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**BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA**

Order Instituting Rulemaking to Continue  
the Development of Rates and  
Infrastructure for Vehicle Electrification.

Rulemaking 18-12-006

**ADMINISTRATIVE LAW JUDGE'S RULING  
DIRECTING PACIFIC GAS AND ELECTRIC COMPANY,  
SOUTHERN CALIFORNIA EDISON COMPANY, AND  
SAN DIEGO GAS & ELECTRIC COMPANY TO RESPOND TO  
OUTSTANDING QUESTIONS ON THE DEVELOPMENT  
OF A SUBMETERING PROTOCOL**

**Summary**

This ruling seeks party comments on questions that are outstanding after a June 2019 workshop regarding the development of a submetering protocol for plug-in hybrid and plug-in electric vehicles (PEVs). This ruling also directs the investor-owned electric utilities (IOUs) to revise and circulate their 2012 *Strawman for Plug-In Electric Vehicle Submetering Protocol*, considering the comments filed and served, and present the revised report at a workshop. Following incorporation of stakeholder feedback into their proposal, this ruling directs the IOUs to file and serve a Plug-In Electric Vehicle Submetering Protocol proposal in this proceeding for party comment and consideration by the Commission.

**1. Background**

The Commission has been evaluating policies to develop infrastructure sufficient to overcome barriers for widespread deployment and use of plug-in hybrid and plug-in electric vehicles in California for almost a decade. One of

these barriers has been how to affordably enable PEV customers to simultaneously enroll in an electric vehicle (EV) specific and residential time-of-use (TOU) rate to measure and appropriately bill EV charging apart from a primary utility meter.<sup>1</sup>

## **2. Decision (D.) 11-07-029**

In 2011, the Commission issued D.11-07-029, which among other things established requirements for the IOUs to develop rules to incorporate customer-owned submeters<sup>2</sup> into their billing and metering system for PEVs or EVs. Decision 11-07-029 required the IOUs to submit a completed Submetering Protocol by July 31, 2012, in addition to setting several interim requirements, including a workshop and roadmap report.

In October 2011, the Commission's Energy Division held a workshop to discuss the issues associated with submetering. Pursuant to D.11-07-029, the IOUs submitted a roadmap report outlining the steps to implement the submetering protocol in January 2012. On January 31, 2012, the assigned Administrative Law Judge issued a ruling directing parties to address additional questions related to the report.

On October 1, 2012, the IOUs submitted a report entitled *Strawman for Plug-In Electric Vehicle Submetering Protocol* (IOU Strawman). The IOU Strawman

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<sup>1</sup> To date, Pacific Gas and Electric Company's EV-B, Southern California Edison Company's TOU-EV-1, and San Diego Gas & Electric Company's EV-TOU tariffs require the installation of a separate utility meter for enrollment. PEV Submetering will eliminate the need to install a second utility meter.

<sup>2</sup> Decision 11-07-029 at 33 defines "submetering" as arrangements in which a submeter measures EV charging apart from the primary meter. This is similar to separate metering in that it uses a dedicated meter for the EV load. However, the submeter is typically located on the customer's side of the primary meter, making it possible to bill EV load and the remaining household load on different rate schedules.

proposed a set of rules and requirements for types of customer-owned submetering technology and configurations that could be used by customers for separately billing their PEV or EV load. Subsequently, Energy Division determined that the IOU Strawman did not sufficiently meet the requirements of D.11-07-029.<sup>3</sup>

On January 8, 2013, the Commission's Energy Division held a workshop and presented a proposal in response to the IOU Strawman. Energy Division's proposal recommended a two-phase pilot to better understand the costs and benefits of PEV submetering in addition to recommending an extension for the IOUs to submit a final proposal on the PEV Submetering Protocol.<sup>4</sup> Following the January 2013 workshop, Energy Division released a proposal, entitled *Commission's Energy Division Proposal for the Development of Electric Vehicle Submetering* (March 2013 Staff Proposal).<sup>5</sup>

The March 2013 Staff Proposal reviewed various submetering scenarios based on the number of customers of record<sup>6</sup> involved in the transaction. The March 2013 Staff Proposal suggested the Commission begin piloting single customer of record submetering, then pilot multiple customers of record.<sup>7</sup> On March 25, 2013, the assigned Commissioner issued a ruling directing parties to

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<sup>3</sup> D.13-11-002 at 3 to 4.

<sup>4</sup> D.13-11-002 at 4; D.11-07-029 at Ordering Paragraph 4.

<sup>5</sup> D.13-11-002 at 4.

<sup>6</sup> D.13-11-002 at 4 to 5: "Customer of record" is defined as anyone that has an account with the utility. In the case of a "single customer of record," one customer is the responsible entity that pays both the submeter load and the primary meter load. "Multiple customers of record" occurs when the submeter customer is different from the primary meter customer.

<sup>7</sup> D.13-11-002 at 5.

comment on the March 2013 Staff Proposal.<sup>8</sup> In general, comments supported using pilots to determine whether PEV submetering should be advanced.<sup>9</sup>

### **3. Decision 13-11-002**

On November 19, 2013, the Commission issued D.13-11-002, modifying the requirements for the development of the PEV Submetering Protocol set in D.11-07-029. Among other things, D.13-11-002 adopted the March 2013 Staff Proposal's roadmap for a two-phase submetering pilot and extended the deadline for the IOUs' PEV Submetering Protocol to February 1, 2016.

Decision 13-11-002 directed the IOUs to support up to 500 eligible submetering participants in each pilot phase, with the pilots running for at least 12 months.<sup>10</sup> The goals of these pilots were to help the Commission understand the cost of implementing submetering, the benefits of submetering to customers, and the total expected demand for submetering.<sup>11</sup> The results of the pilots were to inform the development of a submetering protocol.

Decision 13-11-002 additionally authorized the use of an independent third-party evaluator to study both phases of the submetering pilots.<sup>12</sup> The third-party evaluator was to be responsible for conducting accuracy meter testing, and surveying customers as to their experiences related to both phases of

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<sup>8</sup> D.13-11-002 at 5.

<sup>9</sup> D.13-11-002 at 17.

<sup>10</sup> D.13-11-002 at 47.

<sup>11</sup> D.13-11-002 at 47.

<sup>12</sup> D.13-11-002 at 38: "The evaluator must be selected via competitive solicitation. The Commission encourages their selection and contract commencement prior to the pilot start date. Energy Division will provide advisory input to the evaluator's activities, which must consult with Energy Division quarterly during the pilot."

the submetering pilots.<sup>13</sup> Ultimately, Nexant was selected as the third-party evaluator. Nexant was to present its findings in a Phase 1 report and a final Phase 2 evaluation report (PEVSP Phase 2 Evaluation Report) to help the Commission determine a path forward to implementing a submetering protocol.

#### **4. Submetering Pilots**

On June 27, 2014, the Commission issued Resolution E-4651, approving the two-phase submetering pilots (PEVSP) in compliance with D.13-11-002. In 2015, the first phase of PEVSP launched. In April 2016, Energy Division hosted a workshop to review the first phase of PEVSP's results, and to discuss a second phase. In 2017, the IOUs launched the second phase of PEVSP.

Between the launching of the second phase of PEVSP and February 2019, the IOUs submitted, and the Commission approved, a number of requests for extensions on the deadline to complete the second phase of PEVSP and for the submission of Nexant's PEVSP Phase 2 Evaluation Report. On December 4, 2018, Nexant submitted a draft of the PEVSP Phase 2 Evaluation Report to Energy Division. In February 2019, Energy Division provided substantial comments on Nexant's report, highlighting concerns surrounding the report's accuracy testing, cost analysis, recommendations, and general quality. On April 26, 2019, Nexant revised its PEVSP Phase 2 Evaluation Report and resubmitted it to Energy Division. This PEVSP Phase 2 Evaluation Report is attached to this ruling as Attachment C and is made part of the record of this proceeding.

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<sup>13</sup> D.13-11-002 at 36-38 identifies the following metrics to be included in the PEVSP Phase 2 Evaluation Report: (1) Comparison of the total cost of metering services; (2) Access to PEV tariffs; (3) Multiple Submeter MDMAs and PEVs operating behind a primary meter; (4) Utility disconnection capability; (5) Customer satisfaction; (6) Reliability of Data, Technology, and Service; (7) Service and Technology Innovations; (8) Technology Standardization; (9) Cost minimization.

On May 28, 2019, Energy Division staff served Nexant's PEVSP Phase 2 Evaluation Report on the service list for the instant proceeding, and the predecessor Rulemaking 13-11-007. Energy Division requested that those interested parties answer questions related to Nexant's PEVSP Phase 2 Evaluation Report in an effort to close the revised report's data gaps.

On June 24, 2019, Nexant presented its findings and recommendations from the PEVSP Phase 2 Evaluation Report at an Energy Division workshop. Participants at the workshop raised a number of questions related to Nexant's findings and gaps in its analysis of the submetering pilots. In light of the comments made at the June 2019 workshop, and in addition to responses provided on Nexant's PEVSP's Phase 2 Evaluation Report, it is clear that more information is needed to answer outstanding issues not resolved within the submetering pilots. Answers to these unresolved questions are essential in the advancement and development of the PEV Submetering Protocol.

## **5. Rulemaking 18-12-006 and Next Steps**

In December 2018, the Commission initiated the instant Rulemaking to Continue the Development of Rates and Infrastructure for Vehicle Electrification. The Scoping Memo and Ruling issued on May 2, 2019, included within the scope of this proceeding "policies to support submetering and billing for [zero emission vehicles]." As the submetering pilots are complete, it is time to move forward and set forth a plan for the IOUs to file a Submetering Protocol for the Commission's consideration.

First, to close the data gaps from Nexant's PEVSP Phase 2 Evaluation Report and to provide more information to assist the IOUs in developing a PEV Submetering Protocol, we direct the following:

- (a) The IOUs must file and serve responses to the questions listed in Attachments A and B no later than 20 days after this ruling is issued;
- (b) Parties may file and serve comments responding to the questions listed in Attachment A no later than 20 days after this ruling is issued; and
- (c) IOUs and all other parties may file and serve replies to IOU responses and party comments not later than 30 days after this ruling is issued.

Subsequently, to advance the development and submission of the Submetering Protocol, we direct the following:

- (d) The IOUs must revise their *Strawman for Plug-In Electric Vehicle Submetering Protocol* and host a workshop to discuss their draft revisions not later than 90 days after this ruling is issued. To facilitate productive discussion at the workshop, the IOUs must circulate the *Strawman for Plug-In Electric Vehicle Submetering Protocol* to this service list at least 10 days in advance of the workshop and review any post-workshop informal written comments that parties serve to this service list no later than 10 days after the workshop;
- (e) The IOUs must file and serve a proposed PEV Submetering Protocol to this proceeding, informed by the current record, party comments in response to this ruling, feedback received at the workshop, and post-workshop comments no later than 180 days after the date this ruling is issued; and
- (f) Parties may file and serve comments and reply comments on the IOUs' proposed PEV Submetering Protocol not later than 20 days and 30 days, respectively, after the PEV Submetering Protocol is submitted.

If necessary, the IOUs may request to file the above requested information pursuant to Public Utilities Commission Rules of Practice and Procedure Rule 11.4.

**IT IS RULED** that:

1. Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company are each directed to file and serve responses to the questions in Attachments A and B to this service list not later than 20 days after this ruling is issued.

2. Parties may file and serve comments on the questions in Attachment A to this service list not later than 20 days after this ruling is issued.

3. Any interested party may file and serve reply comments not later than 30 days after this ruling is issued.

4. Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company must revise their *Strawman for Plug-In Electric Vehicle Submetering Protocol* and serve the revised version of the *Strawman for Plug-In Electric Vehicle Submetering Protocol* at least 10 days prior to the date of the workshop ordered in the paragraph below.

5. Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), and San Diego Gas & Electric Company (SDG&E) are directed to host a public workshop to discuss the revised *Strawman for Plug-In Electric Vehicle Submetering Protocol* not later than 90 days after this ruling is issued, and PG&E, SCE, and SDG&E must review any post-workshop informal written comments that parties serve to this service list no later than 10 days after the workshop.

6. Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), and San Diego Gas & Electric Company (SDG&E) are directed to draft a Plug-In Electric Vehicle (PEV) Submetering Protocol, that is informed by the current record, party comments in response to this ruling, feedback received at the workshop, and post-workshop comments. PG&E, SCE, and

SDG&E must file and serve the proposed PEV Submetering Protocol within this proceeding no later than 180 days after this ruling is issued.

7. The revised Nexant report from April 26, 2019, entitled PEVSP Phase 2 Evaluation Report, is attached as Attachment C and is made part of the record of this proceeding.

Dated January 23, 2020, at San Francisco, California.

/s/ PATRICK DOHERTY

Patrick Doherty  
Administrative Law Judge

# **ATTACHMENT A**

*Data Communication & Reliability*

1. During the June 24, 2019, workshop, parties argued that the meter data transfer process tested in the Plug-in Electric Vehicle (PEV) submetering pilot is not a scalable path forward to communicate the meter data recorded on the third-party submeter to the utility billing system. Do you agree with this position? Why or why not?
  - a. If yes, should the PEV Submetering Protocol adopt standards to align the communication process between the third-party meters and the utility billing system? What standards should be considered?
  - b. If no, are there steps that can be included in the PEV Submetering Protocol to improve this process?
2. Southern California Edison Company (SCE) and San Diego Gas & Electric Company (SDG&E) were found to not have stored the PEV submeters raw data sent over by the Meter Data Management Agent's (MDMA) during the PEV Submetering Phase II pilot, which prevented the utilities ability to correct any meter data discrepancies. The Minnesota Public Utilities Commission (MPUC) is requiring Xcel Energy store the raw meter data for 90-days for their PEV submetering pilot program<sup>14</sup>. Do you believe the PEV Submetering Protocol should require the storage of raw meter data for a predetermined period of time? Why or why not?
  - a. If yes, who should be responsible for storing and how long should the raw meter data be stored? Who should bear responsibility to paying the costs to store this data? How should these costs be recouped?
3. Pacific Gas and Electric Company's (PG&E) Electric Program Investment Charge (EPIC) 1.14 report<sup>15</sup> discussed the use of the utility Smart Meter Network or Distribution Automation (DA) Communication to relay a smart device's data to the utility billing system. The report's conclusion was that this option could potentially serve as a more efficient pathway to communicate data from a device to the utility.
  - a. Is there an opportunity to use the DA Communication pathway to relay the data from a PEV submeter to the utility billing network?

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<sup>14</sup> See [Xcel Energy's Compliance Filing](#).

<sup>15</sup> See [PG&E's 2016 EPIC 1.14 - Next Generation SmartMeter Telecom Network Functionalities Report](#).

- b. Will using the DA Communication pathway impact the accuracy or quality of the data received by the utilities compared to the current communication procedures used in the PEV submetering pilot?
- 4. Nexant's evaluation report demonstrated that the customer's WIFI connectivity could be a significant source for the data issues reported to the Investor Owned Utilities (IOU).<sup>16</sup> Do you agree with this position? Why or why not?
  - a. Should the PEV Submetering Protocol pursue WIFI as the pathway to transmitting data from the PEV submeter to the IOU? Why or why not?
  - b. Should alternatives to WIFI be pursued, such as the IOU's Advance Metering Infrastructure network or cellular connectivity? Why or why not?
  - c. Is there another preferable pathway available to transmit the PEV submeter data to the IOUs?
  - d. What are the benefits and limitations of each of the above communication options?
- 5. The SmartPole Demonstration project in PG&E's EPIC 1.14<sup>17</sup> report sought to find a pathway to meter municipal streetlight equipment that previously required either a flat rate, no rate at all, or the installation of a separate utility-grade meter at each light pole. The conclusion of the report suggests the use of a utility-grade smart meter to perform as a submetering offers a successful and scalable option metering option compared to the installation of a separate meter for billing purposes.
  - a. Is the technology tested in this program is a viable alternative to third party submetering? Why or why not?
  - b. Are there any learnings from this program that can inform the development of the PEV Submetering Protocol?

*PEV Submetering Equipment Accuracy*

- 6. Some parties argued at the June 24, 2019 workshop that the current state of third-party submetering equipment can meet the 2% field testing and 1%

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<sup>16</sup> See *California Statewide PEV Submetering Pilot – Phase II Report* at 53.

<sup>17</sup> See [PG&E's 2016 EPIC 1.14 - Next Generation SmartMeter Telecom Network Functionalities Report](#).

laboratory testing meter accuracy threshold requirements<sup>18</sup>, however, there was agreement that it will be difficult to meet the current California Independent System Operator (CAISO) and IOU required 0.2% accuracy threshold<sup>19</sup> for revenue grade meters. Do you agree with this statement? Why or why not?

- a. Is meeting the CAISO and IOU 0.2% accuracy threshold important for enabling PEV submetering? Why or why not?
  - b. If the PEV Submetering Protocol were to include the 1%-2%-meter accuracy threshold for PEV submetering, will this decision be beneficial or detrimental to advancing the adoption of PEV submetering equipment?
  - c. Will a 1%-2%-meter accuracy threshold have policy implications for other applications of the PEV submeter? If so, what applications will be affected?
  - d. Should the PEV Submetering Protocol pursue a temporary meter accuracy threshold to allow the technology to catch up to the current CAISO and IOU standards? If yes, what should the temporary meter accuracy threshold be, and for how long should it be in effect?
  - e. If the PEV Submetering Protocol were to allow a 1%-2%-meter accuracy threshold, how should the IOUs allocate the added costs of accepting the potential meter data errors?
7. Nexant expressed concern at the June 24, 2019 workshop<sup>20</sup> that there were five key drivers for the submeter equipment accuracy and data reliability issues: (1) the submeter equipment, (2) the customer's WIFI connection, (3) the data processing steps, (4) the IOUs process to manage and store data, and (5) voltage errors and voltage drops. Do you agree with Nexant's position that these are the key drivers of data accuracy and reliability issues? Why or why not?

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<sup>18</sup> The accuracy standards for the PEV Submetering Phase II pilot were approved in Advice Letter 4864-E-A/B and informed by American National Standards Institute (ANSI) C12 and National Institute of Standards and Technology Handbook 44 § 3.40.

<sup>19</sup> See [CAISO's Business Practice Manual for Metering V.18 \(2018\)](#), [PG&E's 2017-2018 Greenbook Manual](#), and SDG&E's Electric Commercial Meter Specification Section 4.5.4. SCE's meter standards follow [ANSI C12.20-2015](#).

<sup>20</sup> See Slide 13, 26, and 32 of Nexant's June 24, 2019 Public Workshop Presentation.

- a. Please identify any additional drivers that could have been the source of the PEV submeter accuracy and data issues.
  - b. How should the PEV Submetering Protocol address each of these key issues?
8. In responses to questions proposed by Energy Division (ED) Staff in June<sup>21</sup>, parties recommended the PEV Submetering Protocol adopt equipment testing standards to determine the accuracy of the PEV submetering equipment. Do you support this position? Why or why not?
- a. Are there any equipment testing standards in place for similar technologies that the PEV Submetering Protocol should consider to adopt in lieu of developing new standards?
  - b. What standards should the PEV Submetering Protocol pursue to ensure accurate PEV submetering equipment testing?
  - c. If you do not agree with this position, who should be responsible to the development of standards to test the PEV submetering equipment?

*Standards Applicable to PEV Submetering*

9. Responding to ED Staff questions on Nexant's evaluation report, parties suggested the PEV Submetering Protocol should pursue established standards such as ANSI C12, Institute of Electrical and Electronics Engineers (IEEE) 1547.1, IEEE 2030.5, and Public Utilities Commission Rules of Practice and Procedure 21 Interconnection Requirements. Are there any other standards that should be considered for the development of a PEV Submetering Protocol? If yes, please list the additional standards to consider.
- a. Please explain what the suggested standards will address and the benefits of pursuing them.
10. In January 2019, the Maryland Public Service Commission (PSC) determined that PEV submetering was integral to enrolling residential customers into EV TOU rates and approved<sup>22</sup> three utilities' proposal to enable third party PEV submetering. The Maryland PSC instituted a 5-year waiver of four

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<sup>21</sup> See [Questions on Nexant's PEV Submetering Phase 2 Evaluation Report](#).

<sup>22</sup> See [Maryland PSC Order No. 88997](#).

submetering standards<sup>23</sup> to permit PEV submetering while a permanent pathway is explored. Should a similar model of allowing a scalable PEV submetering program prior to a finalization of the PEV Submetering Protocol be considered by the California Public Utilities Commission (CPUC)? Why or why not?

- a. If you agree, what standards should be waived?

*Outstanding Concerns on Nexant's Evaluation Report*

11. The CPUC ordered the IOUs to test the application of PEV submetering for Multiple Customers of Record (MCOR) in the PEV Submetering Phase II Pilot<sup>24</sup>. Implementation of the pilot identified that too many barriers existed to enroll and evaluate any MCORs<sup>25</sup>.

- a. Please identify the information we currently have that can help move forward with the inclusion of MCORs in the PEV Submetering Protocol.
- b. Please identify the information needed to move forwards with MCOR PEV submetering, and how the CPUC and IOUs should seek to gather this information.

12. Decision 13-11-002 identified thirteen metrics to evaluate the customer experience metrics that were to be addressed in the pilot evaluation report<sup>26</sup>. Do these thirteen metrics collectively encompass all the necessary issues that need to be addressed in the PEV Submetering Protocol?

- a. If not, please identify what additional issues need to be addressed?

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<sup>23</sup> The four temporarily waived standards are [Code of Maryland Regulations \(COMAR\) 20.25.01\(B\)](#) which limits who can own a submeter, [COMAR 20.25.01.04\(A\)\(2\)](#) which requires the submeter type and design to meet the applicable provisions of the latest edition of ANSI, [COMAR 20.50.02.02\(C\)](#) which establishes the latest edition of ANSI as ANSI C12.1-2001, and [COMAR 20.25.01.05\(H\)](#) which allows a property owner to impose a service charge to cover the administration costs of a submeter.

<sup>24</sup> See [D.13-11-002](#).

<sup>25</sup> See *California Statewide PEV Submetering Pilot – Phase II Report* at 12 and 40.

<sup>26</sup> See [D.13-11-002](#) at 36-38.

*General PEV Submetering*

13. Is there a preferred PEV submeter ownership model that the PEV Submetering Protocol should pursue (*i.e.*, utility ownership, third-party ownership, a hybrid model that offers customer choice)?
  - a. What makes this model a better option than the alternative(s)?
  - b. If multiple ownership models should be allowed, what steps, if any, should be pursued to minimize the risk of customers selecting one option over the other(s) due to an inherent favorability bias?
14. Do the IOU administered Demand Response (DR), Renewable Portfolio Standard's Western Renewable Energy Generation Information System (RPS WREGIS), or any other programs share data accuracy, data communication and reporting, technology requirements, or any other PEV Submetering feature that can provide a basis for standards to include in a PEV submetering protocol?
  - a. If yes, please explain how these requirements can apply to the PEV Submetering Protocol and their benefits.
15. Please identify any other outstanding issues or questions related to PEV submetering that need to be addressed to further the development of the PEV Submetering Protocol and the suggested pathway to attend to these issues/questions.

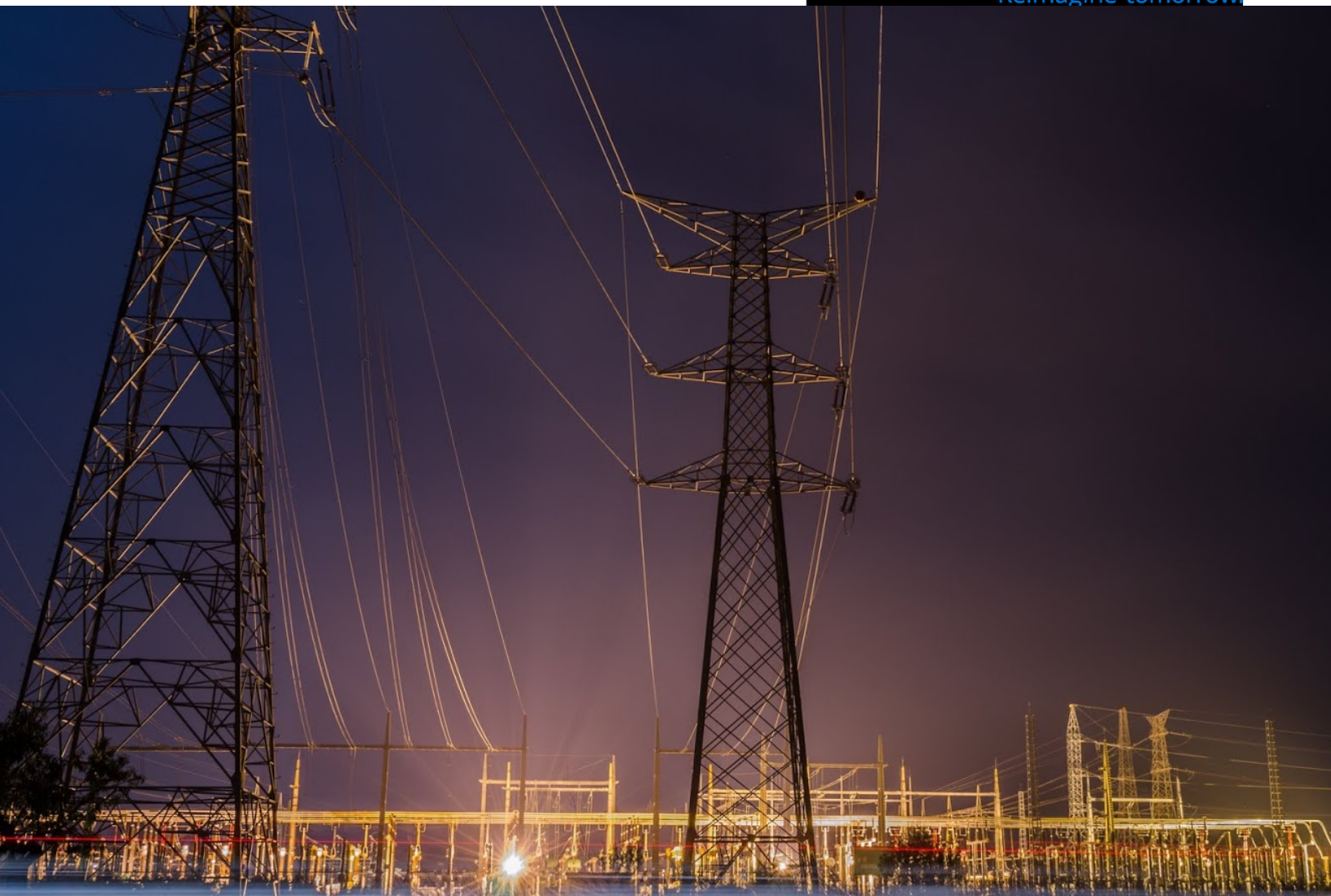
*(End of Attachment A)*

# **ATTACHMENT B**

1. Using an Excel spreadsheet that will be provided to the IOUs by the Commission's Energy Division staff (Utility Submetering Cost Estimate Template), fill in all cells with the expected costs needed to upgrade the current billing system to accept, analyze, and bill customer PEV submetering data. Please indicate how each cost was derived, if the costs are an estimate or precise figure, and if it is a one time or reoccurring charge. Also detail if the expected upgrade costs are limited to PEV submetering or if the upgrades can be used for other IOU programs (ex., Demand Response, Net-Energy Metering, Vehicle-to-Grid Integration).
2. During the June 24, 2019 workshop, Southern California Edison Company commented that the data received from the Meter Data Management Agent (MDMA) cost 30x more to communicate, analyze, and store than data received through the Advance Metering Infrastructure (AMI) network. Please provide an excel file with a tab that details the individual costs to communicate, analyze, and store meter data through the AMI network; a tab that details the costs to communicate, analyze, and store the PEV submetering from the MDMA's; and a summary tab that compares the two networks.
3. During the June 24, 2019 workshop, the utilities mentioned that AMI system upgrades are or will be occurring over the next one to three years for each utility, and will prevent the IOUs from implementing upgrades specific to PEV submetering over this time. Please provide information on what these upgrade entail, such as what features will be affected, how much the upgrades will cost, how long the upgrades will take to perform, what the outcome of the upgrades will support (*i.e.*, SmartMeter communication), why PEV submetering upgrades cannot be included in the current process, how long until the next round of upgrades will be needed, and any additional information that will impact the ability to implement a PEV Submetering protocol.

*(End of Attachment B)*

# **ATTACHMENT C**



# California Statewide PEV Submetering Pilot – Phase 2 Report

Submitted to California Public Utilities Commission

April 26, 2019

**Principal Authors:**

Michael Sullivan, PhD, Senior Vice President

Eric T. Bell, PhD, Principal Consultant

Nicholas L. Cain, PhD, Senior Consultant

Trevor Cummings, Senior Analyst

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# 1 Executive Summary

## 1.1 Introduction

Electric vehicle ownership is growing rapidly in the United States and especially in California, where the state has set a target of having 5 million zero-emissions vehicles (ZEVs) on the road by 2030. Qualifying ZEVs include hydrogen fuel cell vehicles and plug-in electric vehicles (PEVs). This report focuses on PEVs, a category which includes plug-in hybrid electric and battery-electric vehicles.

According to a recent report by the International Council on Clean Transportation, there were more than 366,000 PEVs in California in 2017. And the number of PEVs in operation is growing rapidly: Last year, electric vehicles accounted for 13% of cars sold in San Jose, 7% in San Francisco, and 5% in Los Angeles.

If this rapid growth in PEV ownership continues, it will lead to an increase in demand for electricity. A 2018 study by the National Renewable Energy Laboratory finds that if adoption of PEVs continues to increase, US electricity consumption, driven by transportation and other sectors, could reach a growth rate of 1.6% a year.

As the adoption of PEVs continues to accelerate in California, PEV charging patterns will become an increasingly important factor in the state's electricity system. In a future where PEVs make up a significant share of California's vehicle fleet, charging loads will need to be well-managed to avoid adding significant load to system peaks.

One approach to tracking and managing vehicle charging is through submetering. Submetering allows a customer to access special rates for charging their PEV, independent from the standard utility rate, and without installing a separate utility-grade meter, which can be an expensive addition.

A typical residential customer in California is billed under a tiered pricing structure where the price of electricity increases as aggregate monthly consumption reaches a certain level. Each customer's baseline allowance is calculated based on location, heating source, and other factors. Under this billing structure, charging a PEV can drive up both a customer's rate and their power bill.

Submetering provides an approach to reduce a customer's bill by measuring the electricity used to charge the customer's PEV independently from the residence. This allows utilities to offer special rates that save PEV owners money on electricity—while also eliminating the cost of installing a separate revenue-grade electricity meter.

Under a scenario where the residence or business is on a time-of-use (TOU) rate—that is a rate that varies by time of day—the benefit of submetering is dependent on the difference between the special PEV charging rate and the whole-house TOU rate, plus any additional value that comes from the being able to track and control PEV loads.<sup>1</sup>

---

<sup>1</sup> In 2019 and 2020 millions of residential customers in California will be transitioned to TOU rates. Section 4.6.3.1 provides background on this transition and presents a cost analysis of PEV charging under whole-house TOU and a variety of other rate scenarios.

In order to examine submetering more carefully, the California Public Utilities Commission (CPUC) issued two decisions (D.11-07-029 in 2011, and D.13.11-002 in 2013) that directed California's three large investor owned utilities<sup>2</sup> (referred to throughout this report as the "utilities" or the "utility") to work with PEV stakeholders to assess challenges and opportunities relating to charging PEVs—and to specifically examine the potential for submetering as an approach to provide cost savings to customers while improving the integration of PEVs into the power grid.

## 1.2 Overview of Project and of Evaluation Studies

The California Statewide PEV Submetering Pilot was designed to study the potential for using submetering to provide rates and bills specific to the owners of PEVs. As part of the pilot, which was conducted in two phases, Nexant worked with stakeholders to produce two evaluation reports.

For both phases of the pilot, the enrollment arrangement was similar: a customer signed up with a provider of charging equipment and services, installed a home charging station (via a certified electrician), and signed a service agreement with both their electrical utility and their charging station provider. Since these charging station providers also managed the flow of data from the customer's submeters, they were called Submeter Meter Data Management Agents (MDMAs).

In both pilot phases, we evaluated the strengths and weaknesses of subtractive billing. With this approach to billing, data from a customer's submeter (which records PEV load at 15-minute intervals while charging) is sent via an MDMA to the customer's utility. The utility then subtracts the PEV usage from the whole-house measurements made by the main meter during the same time. This is one approach to permitting utilities to offer PEV-specific rates.

Phase 1 of the pilot enrolled 241 customers (out of a maximum of 1,500) across the territories of California's three large investor owned utilities. The first phase began in early 2014 and the results were published on April 1, 2016. In Phase 1, Nexant worked with stakeholders to:

- 1) Study the service offerings of charging stations and utilities and map their interactions as it pertains to submetering.
- 2) Examine the accuracy of the submeters using loggers placed in a select group of customer locations.
- 3) Survey customers to understand the experience of those who participated in the pilot project.
- 4) Assess, using a different survey, the demand for submetering among PEV owners who were not part of the pilot.

In Phase 2 of the pilot, the objective was to evaluate the submetering process for a larger group of customers,<sup>3</sup> including those who are billed as multiple customers of record (MCOR). MCOR customers often live in multifamily housing or are commercial tenants who sublease. The MDMAs were not able to negotiate and execute the more complex, multiparty customer

<sup>2</sup> The three investor owned utilities that participated in this project are Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E).

<sup>3</sup> The customer limit per utility remained at 500, the same as Phase 1 of the pilot. However, Phase 1 fell short of the number of customers desired for the pilot and the stakeholders were interested in enrolling a greater number of customers in Phase 2 of the pilot.

enrollment agreements (CEAs) required for MCORs given the timelines of the pilot. Consequently, the MCOR scenario was not tested in Phase 2.

Phase 2 took advantage of the stakeholders' experience and lessons learned<sup>4</sup> from Phase 1. Pilot stakeholders include the utilities and MDMAs, and where applicable, CPUC Energy Division staff. Phase 2 included a larger group of participants (449 submeters out of a maximum of 1,500). Stakeholders improved the enrollment process and back-end data flow, tested new equipment, and took advantage of this larger sample size to better understand the customer experience via three separate opinion surveys. Phase 2 also included both a field and laboratory-based study of submeter accuracy.

Work on Phase 2 of the pilot evaluation began in early 2017 and Nexant submitted the report to the CPUC's Energy Division in December 2018.<sup>5</sup> In the Phase 2 evaluation Nexant worked with stakeholders to:

- 1) Review the service offerings of participating MDMAs and create cost estimates for submetering.
- 2) Assess the accuracy of the submeters using loggers placed in a sample of participating customer locations, as well as a separate independent laboratory study to perform a submeter acceptance accuracy test.
- 3) Survey customers to gauge:
  - a) Participants' initial knowledge of submetering and related issues;
  - b) Participants' experiences with the pilot; and
  - c) The experiences of those who dropped out of the pilot or did not complete the enrollment process.

Nexant also evaluated the customer experience by examining questions and complaints sent by customers to the utilities.

Although certain components of these two phases may seem similar, Phase 2 of the pilot built on the work done in Phase 1 and examined similar topics using different evaluation methods. Although we focus on results from the more recent Phase 2 evaluation, we also present key findings from Phase 1 that provide additional insight.

## 1.3 Summary of Results

### 1.3.1 Overview of Service Offerings and Business Processes

For both Phase 1 and Phase 2 of the pilot, Nexant first surveyed the service offerings of the companies working in the PEV charging sector. We interviewed California's utilities and a set of companies that provide charging equipment and submetering services to PEV owners.

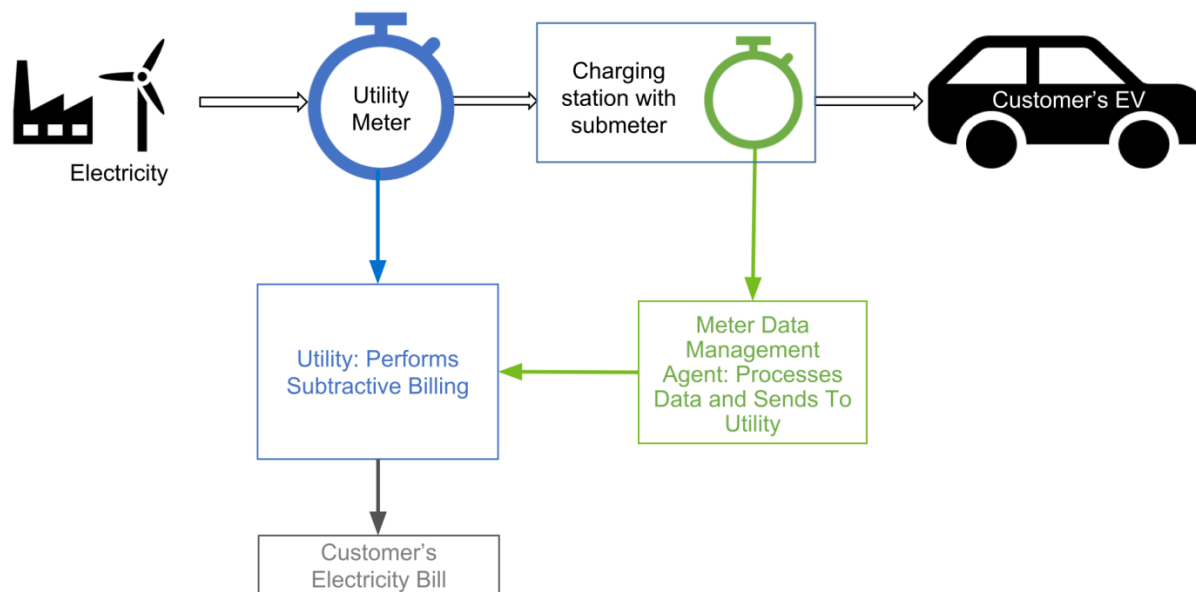
A submeter is a small set of electronic components (or a single chip) that measures the amount of electricity flowing through a circuit. The MDMAs provided the utilities with measurements of PEV electricity usage taken from the customer's submeter, which was either associated with or embedded in a PEV charging station.

<sup>4</sup> Key findings from Phase 1 are contained in Section 2.1.1.

<sup>5</sup> Minor revisions for clarification and an incremental savings comparison were added in April, 2019.

The utilities then subtracted the usage for PEV charging from the total amount of electricity a customer used during the same period as measured by the residence's utility-grade meter. This "subtractive billing" approach allows the utilities to calculate electricity used by the customer to charge the PEV, which is billed at a different rate than the whole-house rate. Once the two bills were calculated they were combined into a single document and sent to the customer at the end of their billing cycle. The data flows and communications between pilot stakeholders are shown in Figure 1-1.

**Figure 1-1: Activities and Responsibilities for Submetering Stakeholders in Phase 2**



### 1.3.2 Demand for Submetering

In Phase 1 of the pilot Nexant administered a survey to assess the demand for submetering among PEV owners who were not part of the pilot. Because this survey was not repeated as part of Phase 2, and because the results may help inform the development of future policies regarding submetering, we briefly summarize the results in this section.

The key finding from this survey: 41% of those surveyed in 2016 said that they would be willing to enroll in a submetering system similar to the one offered in the Phase 1 pilot, provided they could save money on electricity, and/or charging equipment.

Almost 75% of the enrollment decision was driven by the desire to save money on their electricity bill due to submetering. Saving money on the submeter installation (due to incentives outlined in the hypothetical case explained to PEV owners) was also a key driver. Survey questions of this kind are often subject to a positive hypothetical bias—in other words, respondents can overstate their likelihood of signing up for a future program. However, this survey shows that among surveyed PEV owners, there is strong interest in using submetering to save money on PEV charging. For more details on the survey instrument and methodology, please see Section 3.4 and Appendix C in the California Statewide PEV Submetering Pilot—Phase 1 report.<sup>6</sup>

<sup>6</sup> Please see the Phase 1 report for more details: <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453395>

### 1.3.3 Accuracy of Submeters

The accuracy of charging station submeters is crucial to the success of any potential future submetering program because accurate charging data is necessary for accurate bills. Phase 1 of the pilot tested the accuracy of submeters in the field to a standard of  $\pm 5\%$ ; Phase 2 tested submeters in the field to a standard of  $\pm 2\%$ . Phase 2 also included a laboratory test of a small set of submeters to an acceptance testing standard of  $\pm 1\%$ .<sup>7</sup>

In Phase 1 of the pilot, Nexant installed external loggers in a small sample of customer locations to independently measure PEV charging loads. Of the 14 submeters successfully tested, 12 (86%) met the  $\pm 5\%$  Phase 1 accuracy threshold; the other 14% did not.<sup>6</sup>

As part of Phase 2 of the pilot, Nexant again installed data loggers at a small sample of customer locations. For Phase 2 the stakeholders agreed that submeters must meet a deployed accuracy standard of  $\pm 2\%$  in the field and demonstrate an acceptance accuracy of  $\pm 1\%$ .<sup>8</sup> Table 1-1 shows that only 5.2% of submeters met the  $\pm 2\%$  threshold at 15-minute intervals; 9.6% met the  $\pm 2\%$  standard at daily intervals. Nexant also conducted a second set of statistical tests at the threshold of  $\pm 5\%$ ; only 19.2% of the submeters met this standard. More details on the methodology are provided in Section 3.2.1. Detailed results are presented in Section 4.3.

**Table 1-1: Equivalence Testing Results**

% of Customers Passing (15-minute kW Intervals, with +/- 2% Threshold)				
	PG&E	SCE	SDG&E	Total
Chargepoint	0.0%	0.0%	0.0%	0.0%
Kitu		0.0%		0.0%
eMotorWerks	37.5%	0.0%	0.0%	17.6%
Total	15.8%	0.0%	0.0%	5.2%

% of Customers Passing (Daily kWh Intervals, with +/- 2% Threshold)				
	PG&E	SCE	SDG&E	Total
Chargepoint	22.2%	0.0%	0.0%	5.7%
Kitu		0.0%		0.0%
eMotorWerks	42.9%	0.0%	0.0%	18.8%
Total	31.3%	0.0%	0.0%	9.6%

% of Customers Passing (Daily kWh Intervals, with +/- 5% Threshold)				
	PG&E	SCE	SDG&E	Total
Chargepoint	44.4%	0.0%	0.0%	11.4%
Kitu		100.0%		100.0%
eMotorWerks	57.1%	14.3%	0.0%	31.3%
Total	50.0%	8.7%	0.0%	19.2%

<sup>7</sup> The accuracy standards for the pilot were approved in CPUC Advice Letter 4864-E/A/B; see Accuracy Section 3.2 for details.

<sup>8</sup> Same as above.

To gain more insight into the source of the errors, Nexant, in collaboration with the utilities and CPUC Energy Division staff, decided to contract with a third-party testing laboratory to perform bench-tests of the submeters. Two submeters from each manufacturer were delivered to the independent lab, and one of each of the submeters was connected to a panel of load banks that simulated the load of a PEV when charging. The lab's conclusion was that none of the submeters met the  $\pm 1\%$  standard under bench testing. More details on the laboratory portion of the pilot are discussed in Section 3.2.2. The results are presented in full in Section 4.3.2.

### 1.3.4 Customer Experience

A key objective for Phase 2 was to assess the experience of participating customers in order to determine customer benefits under submetering. To that end, Nexant contacted all participants in Phase 2 immediately after enrolling with a request to complete a participant survey (the Welcome Survey) in June 2017. Nexant then sent participants an additional survey request in May 2018 at the end of the pilot (the Post Pilot Survey).

In addition, in order to better understand why customers may have reacted negatively to the submetering pilot, Nexant sent a separate survey to customers who either withdrew from the pilot while it was underway or did not complete the enrollment process.

A total of 372 participants responded to the Phase 2 Welcome Survey. Results show that the two most important sets of motivations for enrolling in Phase 2 were the:

- Ability to pay a lower rate for electricity used by the PEV.
- Ability to save money on the charging station.

Table 1-2 summarizes the motivations for Phase 2 participation. The ability to pay a lower rate for electricity received a top 2 box score of 97%. This means that 97% of customers thought that these considerations were either "somewhat" or "extremely important" to their decision to participate in the pilot. Saving money on the submeter and/or the charging station (94%) were also key drivers according to their top 2 box scores. Please note that totals may not always add up to 100% due to rounding.

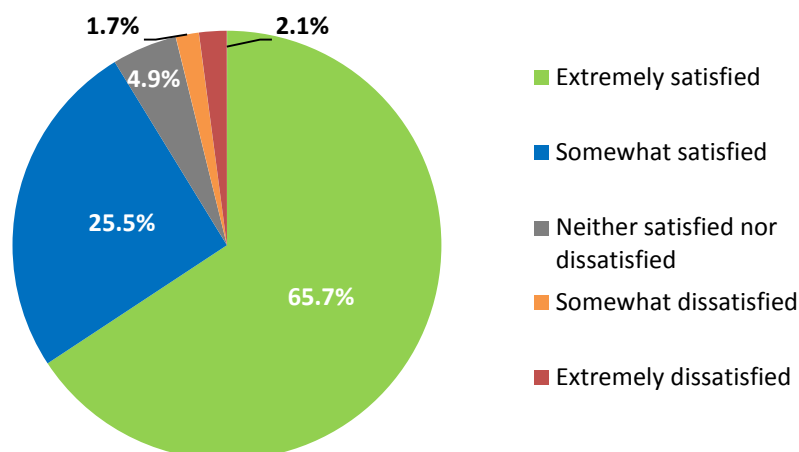
**Table 1-2: Importance of Factors in Deciding to Enroll in the Pilot**

How important was each of the following aspects of submetering in deciding to sign up for the pilot?	Not at all Important	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Ability to pay a lower rate for electricity used by my PEV	1%	1%	11%	86%	97%
The availability of an incentive for the PEV submeter	2%	4%	23%	71%	94%
The cost of the vehicle charging station (including incentives)	4%	5%	31%	59%	90%
Ability to charge my vehicle more quickly	6%	8%	27%	59%	86%
Ability to measure the amount of electricity my vehicle is using	5%	10%	43%	42%	85%
The safety and reliability of the charging station	7%	13%	33%	47%	80%

How important was each of the following aspects of submetering in deciding to sign up for the pilot?	Not at all Important	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
The ability to control the charging station from my smartphone	7%	14%	45%	34%	79%
Other aspects	31%	3%	10%	56%	66%

After the end of Phase 2, approximately 91% of customers said that they were “extremely satisfied” or “somewhat satisfied,” 4% of respondents rated their level of satisfaction as “somewhat dissatisfied” or “extremely dissatisfied,” and 5% responded as “neither satisfied nor dissatisfied.”<sup>9</sup> The disposition of overall customer satisfaction with submetering service from the Post Pilot Survey is presented in Figure 1-2.

**Figure 1-2: Overall Customer Satisfaction with Submetering Service – Post Pilot**



Of the 20 customers who reported being at least somewhat dissatisfied with the pilot, the majority of respondents rated “not enough bill savings” (55%) and “late or inaccurate bills” (50%) as extremely important reasons for their dissatisfaction; registration difficulty was the third most important reason for dissatisfaction.

Of the 10 customers who completed the un-enrolled survey from Phase 2 of the pilot, the majority of respondents (60%) rated “not enough bill savings” as an extremely important reason and another 20% rated it as somewhat important. A breakdown of the reported reasons for un-enrollment is presented in Table 1-3.

<sup>9</sup> Figures may not total 100% due to rounding.

**Table 1-3: Importance of Factors in Deciding to Un-enroll from the Pilot**

How important was each of the following aspects in contributing to your un-enrollment from the pilot?	Not Important at All	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Not enough bill savings	0%	10%	20%	60%	80%
Other billing problems	13%	0%	0%	50%	50%
Errors resulting from submeter accuracy	10%	0%	0%	40%	40%
Late or inaccurate bills	10%	10%	10%	30%	40%
Utility customer service	30%	0%	20%	20%	40%
MDMA customer service	20%	0%	20%	10%	30%
Other technical problems	14%	0%	0%	29%	29%
Other non-technical or billing problems	0%	0%	0%	17%	17%
No longer have an EV	10%	0%	0%	0%	0%

### 1.3.5 Data and Billing Issues

To further assess the customer experience, the utilities also tracked the customer inquiries that they received over the course of Phase 2 of the pilot. The utilities established internal systems to track these issues according to their own categories; Nexant tabulated and analyzed the data.

- SCE reported that the most common inquiries were for program enrollment status (46%), general questions about rates (15%), and questions or complaints about late bills (9%).
- PG&E reported that the most frequent inquiries were for issues with billing accuracy<sup>10</sup> (38%), questions created by enrollment in a conflicting Demand Response program (18%),<sup>11</sup> and general inquiries to better understand the program (10%).
- SDG&E reported the most common inquiries were requests to opt-out of the program (33%); customers also made rate inquiries (22%) and general program inquiries (22%).

More detailed results are provided in Section 4.5.

<sup>10</sup> PG&E determined that billing inaccuracies were due to MDMA data quality issues.

<sup>11</sup> According to the pilot program rules, customers who participate in another Rule 24 demand response program were not eligible to participate in the Submetering Pilot Project. Those who wished to participate in the submetering pilot had to first un-enroll from any conflicting programs.

### 1.3.6 Cost Estimates

The pilot aimed to evaluate whether or not submetering has any financial benefits when compared to installing a separate utility-grade meter. Our research finds that submetering via PEV charging stations (Service Model 2) can save customers around \$350 on equipment and installation as compared to the cost of a separate meter (Service Model 1).

However, to make this technology available at scale across California will require an investment of approximately \$3,000,000 to \$4,500,000 per utility. These funds will go primarily to update the utilities' customer billing systems to automatically calculate the subtractive bills, automate enrollment, and allow submeters to be set-up and closed-out from the billing systems.

Table 1-4 presents a summary of the cost estimate data for installing a Service Model 1 separate utility-grade meter. The top portion of the table contains the costs to the customer, and the lower portion represents costs to the utility.

Under Scenario A, a customer can expect to pay approximately \$1,640 to have a separate utility-grade meter installed. If that customer also elected to purchase and install a charging station, costs would increase by approximately \$1,050 and result in a total (on average) of \$2,723.

The average cost to a utility to install the second meter is approximately \$220. The total cost to a customer and utility is approximately \$1,900 under Scenario A with no charging station, and \$2,943 for Scenario B, which includes the purchase and installation of a charging station.

To allow for a more direct comparison between scenarios, we assumed the customer is starting with no existing PEV charging related infrastructure or equipment in both the utility-grade meter case (Service Model 1) and the submeter case (Service Model 2). Costs related to the service panel installation can include materials, labor, permit, and city inspection.

**Table 1-4: Service Model 1- Traditional Separate Utility Revenue-Grade Meter Cost Estimate**

Paid By:	Cost Component	Average	Range
<b>Customer</b>	Service Panel Related Costs	\$1,640	\$1,600 to \$1,700
	Basic Non-networked Charging Station	\$467	\$179 to \$635
	Charging Station Installation	\$616	\$384 to \$866
	<b>Scenario A: Total Cost with no Charging Station</b>	<b>\$1,640</b>	<b>\$1,600 to \$1,700</b>
	<b>Scenario B: Total Cost with Charging Station</b>	<b>\$2,723</b>	<b>\$2,163 to \$3,201</b>
<b>Utility</b>	Utility Meter & Labor Cost	\$219	\$120 to \$388
	<b>Total Utility Ratepayer Cost</b>	<b>\$219</b>	<b>\$120 to \$388</b>
<b>Total Costs</b>	<b>Total Cost to Customer &amp; Utility: Scenario A</b>	<b>\$1,859</b>	<b>\$1,720 to \$2,088</b>
	<b>Total Cost to Customer &amp; Utility: Scenario B</b>	<b>\$2,943</b>	<b>\$2,283 to \$3,589</b>

Table 1-5 presents the cost estimate for a customer to install a Service Model 2 charging station with an integrated submeter. With the incentive, the average customer is expected to have spent approximately \$866 for the charging station and installation. Charging station prices are publicly available, and summarized in the table below. However, the MDMA's did not have direct

knowledge of the installation costs to their customers, so the data presented reflects estimates from publicly available information on the costs to customers. More details on the cost estimates are contained in Section 4.6.

**Table 1-5: Service Model 2- Customer Cost of Installing a Submeter**

<b>Paid By:</b>	<b>Cost Component</b>	<b>Average</b>	<b>Range</b>
<b>Customer</b>	Charging Station w/ Submeter	\$650	\$500 to \$850
	Charging Station Installation Related Costs	\$616	\$384 to \$866
	Utility Incentives to MDMA, Passed on to Customer	-\$400	N/A
	<b>Total Cost to Customer (With Pilot Incentive)</b>	<b>\$866</b>	<b>\$484 to \$1,316</b>
	<b>Total Cost to Customer (Without Pilot Incentive)</b>	<b>\$1,266</b>	<b>\$884 to \$1,716</b>

Nexant also conducted a billing analysis to understand how customer costs are impacted under various rate structures with and without separate metering of PEV charging. Our key finding was that a general whole-house TOU rate saved customers a little money relative to the tiered rate, but PEV specific whole-house TOU rates and separately metered PEV TOU rates showed potential for greater savings relative to the tiered rate. The incremental<sup>12</sup> annual cost savings of separately metered PEV TOU rates was positive, but it was a small additional amount relative to the large savings achieved by switching from a tiered rate to the PEV specific whole-house TOU rate. Our analysis finds that varying assumptions significantly affects the outcomes, and a comprehensive billing analysis similar to those conducted in the CA Statewide Residential TOU Pilots<sup>13,14</sup> would be beneficial to further understand the full distribution of potential outcomes. A full exploration of this topic, along with details on the rate structures and assumptions used in our estimates are provided in Section 4.6.3.1.

<sup>12</sup> Incremental is defined as the difference between the lowest annual cost under a whole-house rate compared to the lowest annual cost under a rate with separately metered PEV charging.

<sup>13</sup> See: <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453144>

<sup>14</sup> The type of sophisticated billing analysis conducted for the CA Statewide Residential TOU pilots required hundreds of hours to complete and was not in scope for this pilot evaluation.

## 1.4 Key Findings, Conclusions and Recommendations

- Using submetering via a third-party to generate subtractive utility bills is not yet a viable technology for full scale deployment.
- Key issues include: ensuring the accuracy of submetered data; ensuring that meter data and submeter data are synchronized at comparable time intervals; ensuring that submeter data is reliably transferred from the customers via the MDMAs to the utilities; ensuring that bills are accurate and timely; developing a fully automated process for participant sign-up; developing a fully automated billing process that includes standards for data editing, verification, and validation.
- The primary motivations for customers to participate in the pilot were the opportunity to pay a lower rate for electricity used by the PEV, and an incentive payment toward the purchase of a PEV charging station.
- Once customers were enrolled in the pilot, the majority (81%) said that they were “extremely satisfied” and a substantial proportion of participants (46%) shifted their charging to off-peak hours during the pilot, although only about half of those maintained that behavior after the pilot ended.
- Approximately 10% of customers (42), dropped out during the pilot. When asked on a program exit survey why they were leaving, the two most frequently cited reasons for discontinuing enrollment were: “Not enough bill savings” and “Other billing problems.”
- Billing issues experienced in Phase 2 were caused by two problems. First, MDMAs were sometimes late in delivering the submetering usage data to the utilities. This caused customers to receive their bills late or to receive bills with no submetering data (and no savings). Secondly, only about 5% of submeters tested in the field could meet the same accuracy standard as utility-supplied revenue-grade meters.
- The costs to customers to separately meter PEV charging depends on the residence type, and can vary widely due to existing circuits, preferred equipment, and local permits and installation costs. Based on an analysis Nexant conducted for this evaluation, the average customer will spend \$1,640 to install a second utility-grade meter vs. a cost of \$1,266 to install a charging station with embedded submeter.
- Using data from third parties to submeter a customer’s electrical load and create a subtractive bill is viable at the scale of a pilot—however, for the technology to meet the needs of the entire state of California, an estimated investment of \$3,000,000 to \$4,500,000 per large utility is required to modify customer billing systems.
- Nexant believes that development of a more specific submetering performance management standard would help alleviate the potential for different definitions of accuracy and performance, and create an environment of certainty for all parties.<sup>15</sup>
- Nexant also recommends the standard include development and specification of a standard protocol for delivering submetering data to the utilities. Standardization of the submetering data delivery structure will be critical for cost minimization of system implementation for all parties in the data management process.

<sup>15</sup> The accuracy standard was formally specified in the “EV Submeter Pilot Phase 2 Performance Standards for Metering and Meter Data Management Agents” document. However, the specification of the protocols for demonstrating the accuracy is subject to interpretation. The ANSI C12 standard has a number of tests, and going forward it is important to specify exactly which tests are to be conducted, how they are to be conducted, and how the results should be reported.

## 2 PEV Submetering Pilot Background

The California Plug-in Electric Vehicle (PEV) Submetering Pilot was designed to test the submetering process; estimate the cost; and evaluate the experiences of customers, electrical utilities, and companies who provide PEV charging stations with integrated submeters and related services.

To charge their PEVs, customers often use charging stations available from third-party companies known as electric vehicle supply equipment (EVSE) providers. For the California Statewide PEV Submetering Pilot, customers installed either stand-alone submeters with charging stations (used in Phase 1), or charging stations with integrated submeters (used during Phase 2). In either configuration, the submeter measures the amount of electricity flowing to the PEV.

These submeters then report the charging data back to the companies that manage those chargers. As discussed above, for the purposes of this pilot, these charging station providers were dubbed MDMAs. The MDMAs deliver charging data to the utilities for customers that are part of this pilot.

With this additional stream of data, the utilities were able to subtract the electricity sent to the PEV, and bill that usage at a rate independent of the customer's primary rate. As we discuss later in this section, PEV submetering can both help save customers money and improve the grid's efficiency and resiliency. Additional uses for submetering include improving the pricing and management of distributed energy resources (DERs).

In Phase 1 of the pilot, MDMAs offered submeters to customers who were fully responsible (single customer of record or SCOR) for paying for all electricity consumption (including the submeter) at their service location. These were all single-family residences. Phase 1 was a small scale study involving 241 customers across California (out of a maximum of 1,500 possible). After the conclusion of Phase 1 Nexant authored a report that was published by the CPUC on the Plug-In Electric Vehicle (PEV) Submetering webpage:

<http://www.cpuc.ca.gov/general.aspx?id=5938>

In Phase 2 of the pilot, the objective was to evaluate the submetering process again and to include those who are billed as MCOR. MCOR customers often live in multifamily housing or are commercial tenants who sublease. Due to the timelines of the pilot, and the complexities of signing up MCOR customers (which requires multiple customers and the property owner and/or manager to sign the CEA), the MDMAs were unable to recruit any MCOR customers and only SCOR customers were evaluated.

However, Phase 2 of the pilot took advantage of the stakeholders' experience with Phase 1 to study a larger group of customers (449 submeters across the three utilities' territories out of a maximum of 1,500 possible); and improve the enrollment process, back-end data flow, and evaluation.

The remainder of this section provides an overview of the Policy Framework and Evaluation Goals of both Phase 1 and Phase 2 of the pilot (Section 2.1); an overview of the Participants of Phase 2 (Section 2.2), and their respective roles; an overview of the Regulatory History (Section 2.3); and then a brief discussion of Alternative Uses for Submetering (Section 2.4).

## 2.1 Policy Framework and Evaluation Goals

To reduce the air quality and greenhouse gas emissions associated with the transportation sector, California has set ambitious targets for zero-emission vehicles (ZEVs), which include PEVs. Submetering has the potential to contribute to this goal by potentially making home charging of PEVs cheaper, and by better integrating the demand created by charging into the existing power grid.

Submetering a PEV aims to create a lower-cost alternative to installing a full revenue-grade meter to separately meter the PEV load. Submetering has the potential to save customers money on charging by allowing PEV load to be put on a different electric rate than the rest of a residence or facility. And submetering also has the potential to provide benefits to utilities and grid operators; influencing when PEV owners charge through incentives can help align PEV charging with periods of slack demand.

By allowing PEV service providers to deliver this data stream to the customer's utilities, the pilot aimed to test technological innovation and the potential benefits to PEV customers in California.<sup>16</sup>

### 2.1.1 Phase 1 Objectives and Key Findings

Phase 1 of the pilot was designed as an initial test of the submetering process, and focused on SCOR situations where a single customer was responsible for paying for all electricity consumed at their location, as is typical in a single family home.

The objectives for Phase 1, as set out in CPUC Decision [13-11-002](#), were to:

- Identify the different submetering services provided by MDMAs.
- Evaluate the customer experience to determine customer benefits under submetering.
- Evaluate customer demand for SCOR submetering services.
- Evaluate the potential impacts submetering can have on supporting the State's ZEV goals of reducing the costs of PEV home charging and simplifying metering options.

eMotorWerks and OhmConnect customers who participated in the pilot received a full rebate on a WattBox stand-alone submeter (used in Phase 1) in addition to incentive payments of \$100 after installation and \$50 after the first transfer of data from the submeter.<sup>17</sup>

During the course of the pilot the MDMAs and the utilities encountered technical and customer service challenges. One set of challenges was that the manual sign-up process was confusing for customers and time consuming for stakeholders to complete. A second set of challenges was that that back-end process needed to calculate customer bills were mostly manual and thus time consuming for the utilities.

Less than half (46%) of Phase 1 participants rated the sign-up process as either very good, or excellent. Once customers were able to successfully enroll in the pilot, most (72%) said that they were satisfied with the overall service. A small group (15%) of participants reported being

<sup>16</sup> Besides increasing access to TOU rates, submetering also has potential applications as a method to meter DERs. In this application, submetering could be used to aggregate DERs so they can participate in California Independent System Operator (CAISO) demand response markets. See: <http://www.caiso.com/Documents/AgendaPresentation-DistributedEnergyResourceProvider-DraftFinalProposal.pdf>

<sup>17</sup> NRG had only 4 participants in Phase 1 of the pilot, limited to company employees.

dissatisfied with their submetering service and highlighted areas where submetering operations could be improved.

The primary causes of dissatisfaction were inaccurate or increased utility bills, and customer perceptions of poor customer service from the MDMA and/or utility. Thirty percent of customers who responded to the participant survey reported experiencing a problem with their bills—delays were the most common issue—and half of these customers said that their issues had not been resolved by the time of the survey.

In addition, due to the rules of Phase 1 of the pilot, calculating submetered bills required manual processes to transmit customer data from the MDMA to the utilities; enter this data into existing utility billing systems; and calculate the bills. Phase 1 also revealed that submetered data on electricity usage was not always accurate enough for the utilities to calculate customer bills to their required standards.

Phase 1 also included an opinion survey sent to owners of PEVs in California who were not part of the pilot. This survey, which was completed by 626 respondents in early 2016, found that 41% of PEV owners in California were interested in a submetering program similar to Phase 1 of the pilot—provided that they could save money on charging, or save money on the installation of a charging station and/or submeter.

The details on how this adaptive conjoint opinion survey was developed and implemented can be found in Section 3.4.1 and Appendix C of the Phase 1 report, which can be found online at:

<http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453395>

Nexant suggested incorporating three findings from Phase 1 into Phase 2:

- **Streamline the enrollment process** by developing a structured environment for signing CEAs to improve coordination and reduce errors during the sign-up process.
- **Automate subtractive billing** to the extent that these processes can be automated for the small number of customers involved in the pilot.
- **Conduct additional submeter accuracy testing including lab testing.** Given the discrepancies found in Phase 1 the parties agreed to conduct an additional field study using loggers, and laboratory testing of charging station submeters.

Because of the importance of better understanding and quantifying issues surrounding data flows and issue resolution, Nexant recommended including tracking and quantification of data and billing issues in Phase 2 of the pilot.

After the completion of Phase 1, the stakeholders (including charging station providers, utilities, and regulators) held additional scoping meetings and developed a plan for Phase 2 of the pilot that would build on the findings of Phase 1.

### 2.1.2 Phase 2 Evaluation Goals

Phase 2 of the pilot aimed to improve the submetering business processes, test it on a larger group of customers, and extend submetering to customers who are billed as MCOR. MCOR situations often occur in multifamily housing units and commercial business applications. Due to the challenges of enrolling MCOR customers within the relatively short time window available for Phase 2, only SCOR customers participated in the study; however, one SCOR customer was a multi-family residence. We describe the enrollment issues in Section 4.1.

The evaluation objectives for Phase 2 as established in the initial evaluation plan<sup>18</sup> were:

- Identify the different submetering services provided by MDMAs.
- Evaluate accuracy of submetering data collection provided by MDMAs.
- Evaluate the customer experience to determine customer benefits under submetering.
- Track and quantify data and billing issues and issue resolution.
- Establish the submetering protocol to help homeowners access PEV-specific rates.

Although the two phases of the pilot were similar, Phase 2 benefited from the participant's experiences with Phase 1, examined newer submetering technology, and also included a larger group of participants.

Similar to Phase 1, the first part of Phase 2 of the pilot involved gathering information on the services offered by each MDMA and characterizing the interactions between the MDMA, utility, and customer. Given the rapid pace of change in the PEV and charging station sectors, new charging stations were available (or were about to become available), and new players had entered the market. For Phase 2 we also examined the program's costs and created cost estimates for scaling submetering beyond a pilot phase.

After reviewing the service offerings and enrollment process, the next aspect of the pilot involved testing the submeter's ability to maintain accuracy of  $\pm 2\%$  while in field service. To do this Nexant installed data loggers that measured and recorded the flow of electricity through the charging stations at a select group of customers' premises. The readings from the loggers were then compared to the data that the MDMAs provided to check the accuracy of the submeters. All participants in the pilot were asked if they would allow a logger to be installed, and Nexant ultimately conducted accuracy testing on 58 submeters; 13% of the 449 submeters installed in Phase 2.

Because the data loggers identified a relatively high rate of inaccurate submeters, the submeters were also tested in a laboratory setting by a testing firm external to the pilot. For the laboratory study, stakeholders set an accuracy standard of  $\pm 1\%$ . The testing specifications, developed by electrical engineers affiliated with the pilot stakeholders, included a range of different scenarios. Details regarding the submeter accuracy testing are provided in Section 3.2, and results from the evaluation are presented in Section 4.3.

Phase 2 also evaluated the customer experience by surveying participants. For this phase Nexant created three customer surveys: a Welcome Survey at the beginning of the pilot, a survey for participants who withdrew from the program or did not complete the enrollment process, and an end-of-pilot survey of participants. The surveys contained questions that focused on the customer experience but also included, depending on the survey, information on their knowledge of submetering, behavior as it pertains to PEV use and charging, perceptions of stakeholders, and demographic information. Additional background on each of the surveys is contained in Section 3.3 and key findings are presented in Section 4.3. The questions asked in each survey are provided in Appendix B.

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<sup>18</sup> The evaluation plan was based on CPUC Decision D.13-11-002, Resolution E-4651, various Tier 2 Advice Letters, and subsequent scoping meetings held pursuant to the aforementioned CPUC decisions. Please see Section 2.1.3 for the full regulatory history.

Since billing issues were a key source of customer dissatisfaction in Phase 1, in Phase 2 of the pilot the utilities tracked and quantified billing issues and their resolution. This data was then aggregated to provide a summary of key issues. Additional details on the process are contained in Section 3.3 and the key findings are presented in Section 4.5.

## 2.2 Overview of Participants

Three MDMAAs participated in Phase 1: EVgo, OhmConnect, and eMotorWerks. And three MDMAAs participated in Phase 2: ChargePoint, eMotorWerks, and Kitu Systems. Only eMotorWerks participated in both Phase 1 and Phase 2.

In both phases, the MDMAAs were responsible for managing customer relationships during the pilot. This included recruitment, providing (for purchase) charging stations with embedded or associated submeters, enrolling customers in the pilot, and providing customer service and support. MDMAAs measured PEV electricity usage through the submeters and were obligated to deliver data to the utilities for billing purposes on a daily, or near-daily, basis.

The principal responsibilities of the three utilities included processing enrolled customers, setting up separate submeter service accounts within their billing systems, performing subtractive billing for pilot participants, and providing additional customer support. Subtractive billing requires taking the submetered PEV usage data from the MDMAAs, subtracting it from the whole-house usage, and providing the customer with a bill that reflected the appropriate rates for each of the two usage streams.

Because all participants in Phase 2 were single customers of record, the bill was sent to customers as a single document that showed the breakdown between each of the two components—PEV, and rest-of-house. Additional details on the SCOR and MCOR scenarios and how they differ from each other are provided in Appendix D.

The steps for customers to participate in the pilot were:

- Customer learned about the program through marketing materials provided by the MDMAAs, or by word of mouth.
- Customer expressed interest in participating to one of the three MDMAAs, who in turn created an online account (optional) if they were not already a customer of the MDMA, and completed a pre-qualification checklist to ensure the customer met the pilot eligibility criteria (see Section 4.1.2 for a full list) for installing a submeter.
- Customer purchased a charging station with an embedded submeter from the MDMA (with a \$400 incentive provided by the MDMA as detailed in Section 4.6.2.1).
- Customer worked with the MDMA to install the charging station using a third-party California licensed contractor to ensure safety.
- Customer completed a CEA and sent it to the MDMA, who then completed their portion, checked the info, and sent it on to the utility.
- A new submetering account was created by the utility.
- Customers began charging their vehicle using the charging station and sending charging data from their submeter to the MDMA via home Wi-Fi; this data was then sent to the utility and saved in the customer's submetering service account.

The charging stations provided by the MDMAs varied in configuration, but each system contains the electrical components needed to safely connect the PEV to electrical circuits at the premises; a submeter, which measures the amount of electricity used to charge the PEV; and various control and communication circuitry that controls the charging station, stores the information gathered by the submeter, and transmits it to the MDMA via Wi-Fi (a wireless connection). The MDMAs had similar offerings of charging stations with submetering and other value added services including online portals to remotely control charging and view charging data. eMotorWerks also offered demand response program participation.

ChargePoint developed an in-house charging station for Phase 2; while eMotorWerks began Phase 2 with equipment from AeroVironment, and then in a few cases used their in-house-developed JuiceBox. Kitu customers also offered a charging station created by AeroVironment. The equipment available for the customers varied by MDMA and contained different components but was functionally similar, as shown in Figure 2-1.

**Figure 2-1: charging station Equipment Available by MDMA**



MDMAs used their own funds to market the pilot through Cleantech and EV-type publications (news and articles), Google Ad Words, adding a banner to the MDMA website, customer newsletters, Facebook ads, and via notifications to existing customers in the MDMA's respective apps. To enroll, customers were required to fill out a CEA<sup>19</sup> with their MDMA who would submit it to the utility to set-up the submeter account.

<sup>19</sup> CEAs were similar for each utility and contained the terms and conditions of the pilot, a list of eligibility criteria, a description of the duties and obligations of the participant and utility and a form to provide information related to the submeter. CEAs could be

The enrollment period for Phase 2 began on January 16, 2017, and the pilot ended by April 30, 2018 for most customers.<sup>20</sup> Total participation at the end of the enrollment period consisted of 449 submeters: 240 at PG&E, 151 at SCE, and 58 at SDG&E. The majority of participating customers enrolled through either ChargePoint (377) or eMotorWerks (69), with 3 enrolling via Kitu Systems. We cover the enrollment in Phase 2 in greater detail in Section 4.1.

**Table 2-1: Phase 2 Parameters<sup>21</sup>**

Pilot Program Parameters	
<b>Pilot Term</b>	15 ½ Months, beginning January 16, 2017 and ending April 30, 2018
<b>Enrollment Incentive Payment From the Utilities to MDMA</b>	\$210 Per Enrolled Participant (One-Time) \$17.50 Per Month Per Submeter for Data Management
<b>Incentive Cap</b>	Payments to the MDMA end after 12 utility billing cycles
<b>Participation Cap</b>	500 Submeters Per Utility (Including Max 100 Submeters Per Utility for Net Energy Metered (NEM) Accounts)
<b>Submeter Limit</b>	19 Submeters Per Primary Utility Meter Participants may not use multiple levels of submeters
<b>Disenrollment</b>	Customer may contact utility to request an early voluntary termination at any time during the pilot
<b>Dispute Resolution</b>	MDMA is single point-of-contact for all submeter data issues Utility is single point-of-contact for all utility billing issues
<b>MDMA Services</b>	Provide charging stations with submeters for purchase by customers and provide ongoing data services to customers who own their submeters.

rejected by the utility if customers did not meet the eligibility criteria or if the CEA contained any missing, incorrect, or crossed-out information. CEAs with issues were sent to the MDMA for resolution with the customer.

<sup>20</sup> The exact timing of when a customer's pilot varied because the study lasted for 12 monthly billing cycles from the date of enrollment.

<sup>21</sup> From July 1, 2016 Advice Letters

<b>MDMA Services (Continued)</b>	Provide properly formatted, accurate, and timely data to utility
<b>Billing Payment</b>	Submeter service will be terminated for customers who fail to pay. <sup>22</sup> PG&E and SDG&E pay commercial TOU submeter participants \$20 per month per submeter. SCE had available commercial PEV rates, unlike the other utilities, and did not offer \$20 per month per submeter.
<b>Submeter Installation</b>	Must be installed by a person or entity with a Contractor's License issued by the California Contractors State License Board
<b>Informing Customers about Submeter Data</b>	
<b>MDMA Responsibilities</b>	Provide customers with submeter data through a web-based or mobile phone application, or provide data via customer request.  If data does not match the submeter data sent to the utility, the MDMA must notify the customer of the discrepancy and update the online data to accurately reflect the billing information sent to the utility.
<b>Utility Responsibilities</b>	The utility is required to separately report submeter usage and the household usage less the submeter usage through the customer's monthly bill.
<b>Submeter Data Transfer from MDMA to the utility</b>	
<b>Data Delivery Deadline</b>	Data is transferred within 3 calendar days of the utilities' regularly scheduled meter read date. Any data submitted after 5 PM Pacific Time of the third day will not be incorporated into the customer's bill. <sup>23</sup>
<b>Process Updates</b>	Utilities may make periodic changes to the standard format for the MDMA to submit meter data.

<sup>22</sup> All uncollected usage and usage after termination will be the responsibility of the Primary Meter customer.

<sup>23</sup> The three calendar day standard may be met by providing daily submeter data throughout the course of the month

## 2.3 Regulatory History

Stakeholders came together at a 2011 workshop on PEV submetering organized by the CPUC Energy Division staff. This workshop catalyzed research to assess the feasibility of using submetering to reduce barriers to the adoption of PEVs.

A key outcome of this work was CPUC Decision 13-11-002 and Resolution E-4651, which directed the utilities to develop a two phase pilot study to better understand the costs and benefits of PEV submetering.<sup>24</sup>

Key regulatory milestones related to PEV submetering are listed below:

- **July 14, 2011:** CPUC Decision 11-07-029 established policies to overcome barriers to electric vehicle deployment and comply with Public Utilities Code Section 740.2.<sup>25</sup>
- **November 13, 2013:** CPUC Decision 13-11-002 modifies the utilities' requirements for the development of the Submetering Protocol.
- **June 26, 2014:** CPUC Resolution E-4651 approved the utilities' request to implement a PEV Submetering Pilot.
- **July 10, 2014:** Utilities submitted revised Submetering Tariff and Agreements in compliance with Resolution E-4651.
- **July 11, 2014:** Submeter MDMAs provided notice to the CPUC of their participation in Phase 1 of the pilot.
- **July 23, 2014:** CPUC Energy Division staff held meeting with the utilities and MDMAs to discuss the processes to be completed during pilot operations.
- **August 7, 2014:** CPUC Energy Division staff approved the utilities' revised Submetering Tariff and Agreements.
- **February 27, 2015:** CPUC's Director of Regulatory Affairs approved an extension of project deadlines.
- **April 20, 2015:** CPUC Energy Division staff approved the utilities' second revision to Submetering Tariff and Agreements.
- **September 28, 2015:** CPUC's Director, State Regulatory Affairs approved an additional extension of project deadlines (File No.: A.14.04-014 and R.13-11-007).
- **April 12, 2016:** CPUC Energy Division staff hosted a workshop to review the results of Phase 1 and discuss Phase 2.
- **July 1, 2016:** PG&E submitted Advice Letter 4864-E, SCE submitted Advice Letter 3427-E, and SDG&E submitted Advice Letter 2910-E to set out details of Phase 2.
- **November 18, 2016:** CPUC Energy Division approved PG&E Advice Letter 4864-E/A/B, SCE Advice Letter 3427-E and 3427-E-A, and SDG&E Advice Letter 2910-E/E-A/E-B.

<sup>24</sup> Resolution E-4651 also approved a pro forma rate schedule for use in the pilot (PEVSP). See <http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M097/K049/97049639.PDF> for additional details.

<sup>25</sup> Public Utilities Code Section 740.2: The commission, in consultation with the Energy Commission, State Air Resources Board, electrical corporations, and the motor vehicle industry, shall evaluate policies to develop infrastructure sufficient to overcome any barriers to the widespread deployment and use of plug-in hybrid and electric vehicles. Source: <https://codes.findlaw.com/ca/public-utilities-code/puc-sect-740-2.html>

- **November 1, 2017:** CPUC's Managing Director, State Regulatory Affairs approved an extension of project deadlines (File No.: R.13-11-007).
- **August 31, 2018:** CPUC's Director, Regulatory Relations approved an extension of deadline for the final report.

Regulatory compliance with the requirements outlined in Decision 13-11-002, Resolution E-4651, and related Tier 2 Advice Letters are addressed in Appendix C.

## 2.4 Alternative Applications for Submetering

Along with driving the development of the PEV market, California is promoting the use of DERs. DERs are resources—solar, battery storage, fuel cells, PEVs, and other systems—that are relatively small-scale and sited close to the end-use.

The deployment of these resources poses significant challenges for electricity distribution systems and for the utilities that must balance and price these small-scale, distributed resources. Inexpensive and reliable submeters can also be useful in meeting these challenges in the following ways:

- 1) **Providing load and energy measurements needed to appropriately compensate distributed energy systems for the services they provide to the grid.** Utilities in California have offered NEM rates to residential and commercial customers since the mid-1990s. Historically, customers on these rates have been charged only for the energy they used in excess of the energy supplied by their solar system or DER, and were compensated for the energy they supplied to the grid at retail rates up until a certain threshold. NEM rates were revised in 2016 (NEM 2.0) to require a small one-time interconnection charge (~\$120) and a \$0.02/kWh charge for public services. NEM creates several problems, such as:
  - a. It is difficult to fashion a NEM rate that does not over or under-compensate owners of solar systems for the value of the energy they supply to the grid—because the value of the resource varies depending on its location on the grid and the time of day.
  - b. Because NEM rates compensate system owners based on current retail rates, the future value of the revenue stream that will result from an investment in solar is increasingly unpredictable. This problem is becoming more apparent as the timing of the system peak is changing, leading to shifting TOU rate periods and price differentials, and diminishing the value of solar investments compensated under NEM rates.

Both of these serious problems can be mitigated by the implementation of tariffs that compensate customers for the entirety of their solar generation based on an administratively-set or market-set value. However, such tariffs require reliable interval measurements of the energy that solar systems supply to the grid—an important future application of submetering.

- 2) **Providing load and energy measurements necessary to support the implementation of distributed storage for multiple use applications.** Because a significant fraction of electricity demand occurs when renewable resources are not available (i.e., at night), energy storage is an important component to take full advantage of renewable resources. Today, behind the meter energy storage can participate in the

CAISO market via demand response programs that do not require a submeter. However, when a battery seeks compensation for sending energy back into the system (exporting), a submeter will be advantageous to ensuring that distributed resources can be efficiently priced and integrated.

- a. Moreover, compensating energy exports from storage will require the installation of revenue quality meters to record the amount of energy that is delivered to the grid over meaningful time intervals. This is essentially the same issue and technological requirement needed to support feed-in tariffs.

The above requirements are two important applications that can be anticipated today. There are undoubtedly others that will emerge as DER technologies evolve in the near term future.

Now that we have provided an overview of Phase 1 and Phase 2 of the pilot, summarized the regulatory history, and briefly discussed some alternative uses for submetering, we next turn, in Section 3, to provide details on each of the various components of Phase 2 of the pilot. Then, in Section 4 we present results from the study.

## 3 Evaluation Methodology

There are five principal components of Phase 2 of the pilot:

- 1) An analysis of MDMA and utility business processes.
- 2) An assessment of the accuracy of the submetering devices used during the pilot.
- 3) A set of surveys to assess the attitudes and behaviors of pilot participants.
- 4) Tracking and quantification of customer questions and issues relating to the submetering pilot.
- 5) An estimate of the costs or cost savings associated with offering submetering.

In this methodology section, we provide detailed information on the first three methods listed above; information on the last two components is contained in Section 4.

### 3.1 Service Offerings and Business Processes

Since PEVs are an emerging industry, many of the details about the structure of business models, and available opportunities involving third-party submeters are either new, or have yet to be determined. This portion of the analysis involved gathering information on the services offered by each MDMA; characterizing the interactions between the MDMA, utility, and customer; and defining the business model employed by each MDMA under submetering.

In order to analyze the business models that the MDMA employed—and could potentially employ in the future—it was necessary to collect information about several aspects of their business operations including:

- Charging devices and metering technologies that MDMA offered during Phase 2 (including relevant certifications for safety and meter accuracy).
- MDMA and utility business processes to establish the submetered service including:
  - How submetering services were installed at customers' sites.
  - How utilities and MDMA coordinated customer billing.
  - How MDMA provided ongoing service to customers.
  - How utilities and/or MDMA communicated with customers related to submetering inquiries.
- MDMA marketing strategies and tactics used in Phase 2.
- Any additional PEV services offered by MDMA (if any).

This information was collected through data requests and individual phone interviews conducted with representatives from each MDMA and utility. The stakeholders who were interviewed for this part of the evaluation are shown in Table 3-1.

**Table 3-1: Stakeholder Interviews Conducted for Phase 2**

Organization	Person(s) Interviewed	Title/Role	Interview Date
<b>ChargePoint</b>	Newonda Nichols	Program Manager	3/27/2017
<b>eMotorWerks</b>	David Schlossberg	Program Manager	3/29/2017
<b>NRG<sup>26</sup></b>	Mike Ferry	Program Manager	3/28/2017
<b>PG&amp;E</b>	Morgan Metcalf	Program Manager for Submetering Pilot	4/6/2017
	Samantha Leach	Project Manager for Submetering Pilot	
<b>SDG&amp;E</b>	J.C. Martin	Project Manager for Submetering Pilot	4/11/2017
	Thomalyn Lewis	Operations Support Services Associate	
<b>SCE</b>	Al Shepetuk	Project Manager for Submetering Pilot	3/13/2017

Interviews lasted for 30 to 60 minutes and focused primarily on the operations, marketing activities, and customer service of the utility/MDMA during Phase 2 of the pilot. Additional topics of interest included how each stakeholder interacted with customers, the effectiveness of MDMA and utility cooperation, and any particular challenges that were encountered during the pilot. Separate banks of interview questions were prepared for the MDMA and the utilities and are provided in Appendix A.

After completing each interview, notes were compiled and cross-checked against other interviews for potential areas of consensus and/or disagreement. The information gathered during the interviews helped inform the development of the surveys used to evaluate the customer's experience during the pilot, and served to inform the conclusions presented in this report.

## 3.2 Submeter Accuracy

Table 3-2 provides a summary of the submeter accuracy requirement in Phase 2. A threshold of  $\pm 2\%$  was set to be the maximum allowable field error tolerance for participating submeters.<sup>27</sup> Meter acceptance conditions under a laboratory setting were required to be within a  $\pm 1\%$  tolerance.<sup>28</sup> The  $\pm 2\%$  and  $\pm 1\%$  "accuracy" thresholds as described in the prior two sentences are equivalent to the same term used in the ANSI C-12 standard, or equivalent to "tolerance" in NIST Handbook 44 Section 3.40 T.2.<sup>29</sup> Two independent efforts were conducted to evaluate the accuracy of the submeters. First, data loggers were installed at a sample of 58 participant premises to determine whether each device met the  $\pm 2\%$  field accuracy threshold. Second, two

<sup>26</sup> NRG was involved early on in Phase 2, but later dropped out of the pilot. Kitu Systems was a late addition to the pilot and was not interviewed.

<sup>27</sup> The  $\pm 2\%$  accuracy requirement while in service in the field is the same requirement the utilities have for their smart meters.

<sup>28</sup> Utilities require  $\pm 0.5\%$  acceptance accuracy for smart meters.

<sup>29</sup> See NIST document page 3-160: [https://www.nist.gov/sites/default/files/documents/2016/11/10/hb44-2017-web\\_final.pdf](https://www.nist.gov/sites/default/files/documents/2016/11/10/hb44-2017-web_final.pdf)

sample submeters of each type were sent to an independent third-party laboratory for bench testing at the  $\pm 1\%$  accuracy threshold. Details regarding the implementation and approaches used in this testing are covered in the following sections.

**Table 3-2: Submeter Accuracy Requirements**

<b>Submeter Certification and Performance Requirements</b>	
<b>Submeter Certification</b>	<p>Must be certified to Underwriters Laboratories (UL) standards by an Occupational Safety &amp; Health Administration (OSHA)-approved Nationally Recognized Testing Laboratory (NRTL).</p> <p>Safety standard requirements can be fulfilled by providing the utilities with documentation of compliance to prove performance standard requirements.</p>
<b>Submeter Accuracy<sup>30</sup></b>	<p>Demonstrate Meter Acceptance Accuracy of <math>\pm 1\%</math></p> <p>Must Maintain Accuracy of <math>\pm 2\%</math> During Phase 2 of the pilot.</p>
<b>Standard Time Synchronization</b>	<p>Synced to Universal Time Coordinate time standard as defined by NIST, and within <math>\pm 2</math> minutes of UTC<sup>31</sup> while charging station in service.</p>
<b>Unit of Measure</b>	<p>Nearest Watt-hour for each time interval.</p>
<b>Meter System Testing</b>	
<b>Field Testing Sample</b>	<p>An independent third-party evaluator will be allowed to field test up to 5% of the PEV submeters within each of the utilities' service territories.</p>
<b>Field Testing Methodology</b>	<p>MDMAs will propose methodologies for testing and calibration for utility review, consent, and implementation.</p>

<sup>30</sup> Equivalent to the same terms used in the ANSI C-12 standard.

<sup>31</sup> The intent of this, though not explicitly stated in the advice letters, is 2 minutes over a seven- day period, or an accuracy of  $\pm 0.02\%$  accrued at any given time.

### 3.2.1 Nexant Analysis

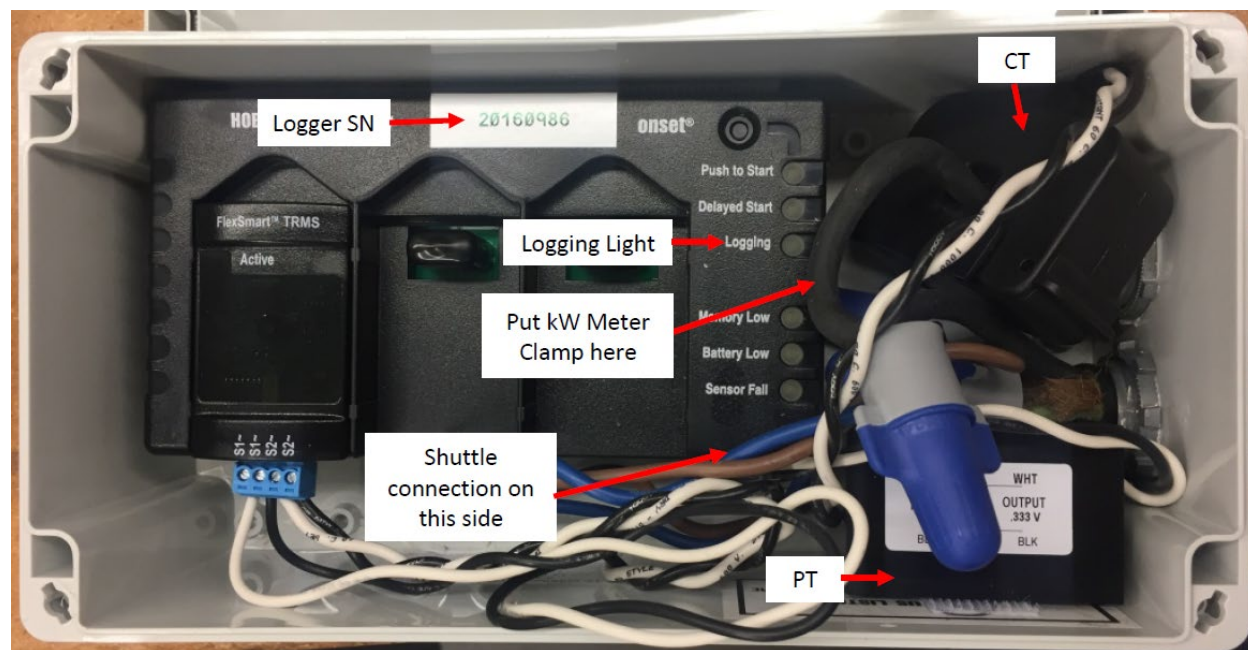
#### 3.2.1.1 Logger Installation and Recovery

The submeter field performance criteria for Phase 2 are submeter measurement of electric load within  $\pm 2\%$ , and time synchronization of  $\pm 0.02\%$  of UTC, equivalent to no more than  $\pm 2$  minutes over 7 days.<sup>32</sup>

In order to become a provider for the pilot, MDMAs were required to submit documents affirming the UL certification of their devices. These documents were submitted to CPUC Energy Division staff, and then forwarded to the project manager who checked the UL-certification in a public database and employed technical experts affiliated with SDG&E to review submeter testing results. However, in developing the evaluation plans for the Phase 1 and Phase 2 pilots, the utilities and CPUC staff agreed to further in-field testing to ensure the accuracy of the charging stations while in operation.

To carry out the in-field testing, Nexant installed loggers which were capable of measuring the electric load on circuits to within  $\pm 0.5\%$ . These devices can also assess the timing accuracy of the charging stations. In Phase 2 loggers were set to record data in 5-minute intervals. Primary usage meters and submeters recorded data in 15-minute intervals. The logger kit, as shown in Figure 3-1, included the following equipment: Onset HOBO-H22 logger, TRMS sensor, 50A CT, enclosure, and power cable with either 6-50, or 14-50 plugs and receptacles.

**Figure 3-1: Onset Hobo Energy Logger H-22 with FlexSmart TRMS Module**



Nexant recruited locations for installing the loggers by asking all participants in Phase 2 if they would host a logger. Fifty-eight customers who agreed had loggers placed on their premises. To do this, Nexant hired field engineers with experience in installing and recovering data logging equipment to install the loggers in the field on a rolling basis (i.e. as soon as possible after

<sup>32</sup> During an initial coordination call with utility meter subject matter experts (SMEs), it was established that the intent of this measure is 0.02% accuracy, or within 2 min of UTC over a period of 7 days. In advice letters, however, this was simply written as 2 minutes during the pilot.

recruitment). Prior to installation, the field deployment and recovery labor force received extensive training in safety protocols, customer contact protocols, as well as installation and recovery procedures.

Nexant then assigned the field engineers to install the loggers on targeted premises. The appointments were set and managed by Nexant's customer experience laboratory and transmitted to the field team members a few days in advance of the appointments. Customers received reminder calls on the day of the installation, and the field representatives called each customer when they were in route to their location with an expected time of arrival. Logger installation started on July 20, 2017, and all loggers were removed from the field by September 13, 2017. Over the course of Phase 2, 58 unique loggers were used for an average of 20 days per installation.

### 3.2.1.2 Accuracy Measurement

Submeter accuracy was determined by comparing the usage information obtained from the data loggers for the relevant measurement periods with the usage information for the same periods as recorded by the submeters and supplied by the MDMA.<sup>33</sup>

The analysis utilized an equivalence testing approach for identifying the magnitude and statistical significance of the difference between the kWh measurements obtained from the loggers and those supplied by the MDMA. The null hypothesis for the statistical tests was that the differences between the MDMA measurements and the logger measurements were *greater than*  $\pm 2\%$ .<sup>34</sup>

An equivalence test was conducted for each logger and MDMA pair in the evaluation. Logger readings were taken at 58 different submeter installations. That is, there were 58 separate tests of accuracy of the logger measurements. Two kinds of equivalence tests were performed; a test of the difference of means (for submeters and loggers) and regression modeling. The difference of means tests were performed using a paired comparisons t-test in which the average difference between the logger consumption reading and the MDMA consumption reading was measured.

In a paired comparison t-test, the difference between the logger measurement and the MDMA usage measurement is calculated for each time interval and the average and standard deviation of the difference between these measurements over all time intervals is calculated. In practice, each equivalence test for 15-minute intervals involved the calculation of ~2,000 difference measurement pairs (assuming 3 weeks of logger observations at 15-minute intervals). Equivalence tests for daily usage involved about 21 measurement pairs for each test.

Based on the means and standard deviations of the differences between the logger and MDMA usage measurements, Nexant calculated confidence intervals for the difference observed in

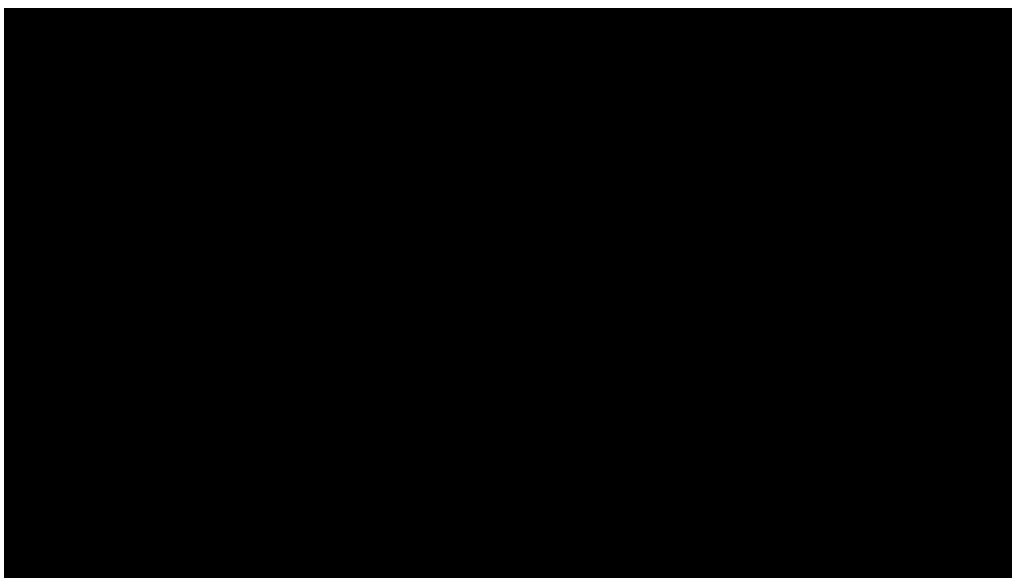
<sup>33</sup> This is the same data that was transferred to the utilities for billing purposes.

<sup>34</sup> For a primer on equivalence testing, see Rogers et al. (1993) "Using Significance Tests to Evaluate Equivalence between Two Experimental Groups". In a traditional hypothesis testing framework, the null hypothesis would have been that there was no difference between the logger and the submeter measurements. The p-value associated with such a test can be interpreted as the probability that any observed difference occurred by chance. A high p-value above the standard 0.05 or 0.10 thresholds does not confirm that the null hypothesis is true, but rather fails to provide evidence that it is false (statistically, these two things are not equivalent). Equivalence testing avoids this problem by setting up the problem up in such a way that a small p-value provides more direct evidence that the submeter is accurate within the acceptable range.

each equivalence test. A confidence interval is the upper and lower limit within which the outcome of a test is expected to occur with a specified probability given random variations in factors that can influence the measurements in the test. In this case, the 95% confidence interval was chosen. The 95% confidence interval is the upper and lower limit within which 95% of the tests will occur if a difference of a given size (i.e.,  $\pm 2\%$ ) or less is present given random sampling.

This equivalence test is designed to determine whether the submeter measurements are within  $\pm 2\%$  of the logger measurements. This range defines what is called the equivalence band. In situations where confidence interval lied entirely within the equivalence band (i.e.,  $\pm 2\%$ ), the null hypothesis (inaccuracy) was rejected and a submeter was classified as accurate. This approach is equivalent to conducting two one-tailed hypothesis tests simultaneously<sup>35</sup> and is shown graphically in Figure 3-2.

**Figure 3-2: Conceptual Depiction of Equivalence Testing for Two Means**



It is also possible to use regression modeling to perform equivalence testing. Using regression modeling, instead of a difference of means calculation, the equivalence test is performed by statistically regressing the MDMA usage measurement for each point in time with the logger measurements for the same point in time. The regression is estimated as a simple linear model in which MDMA usage is expressed as a linear function of the logger measurement for the same point in time.

It is possible to visualize the results of this approach to equivalence as a Cartesian graph with the submeter reading displayed on the y axis and the logger reading displayed on the x axis. The x,y pairs are the measurements at each point in time. The slope of the regression line in the event that the submeter and logger measurements are equal is 1. That is, the submeter measurement is equal to 1 times the logger measurement. If the submeter measurements are on average less than the logger measurements, the slope of the regression line will be less than

<sup>35</sup> The two tests are that the mean difference between submeter and logger readings is greater than the lower bound of the equivalence band and less than the upper bound.

1 and if they are on average greater than the logger measurements the regression line will be more than 1. It is possible to calculate a confidence interval for the regression line.<sup>36</sup>

In this case, a confidence interval for the estimated slope coefficient from the regression was compared to an equivalence band of  $\pm 2\%$  defined around the 45 degree line. Similar to the means case, a confidence interval that lied entirely within the equivalence band for both parameters resulted in rejecting the null hypothesis and concluding that a submeter was accurate to within  $\pm 2\%$ . Once these statistical tests have been run, it is possible to express the accuracy across all the tests by calculating the percentage of the tests for which the submeters passed the accuracy test.

### 3.2.2 Third-party Party Lab Testing

After Nexant began to analyze the logger's accuracy data and found a large number of the devices did not meet the accuracy standards, Nexant and the utilities—in consultation with the CPUC Energy Division staff—agreed in May of 2018 to subject the charging stations to additional third-party laboratory testing.

Two samples of each charging station and integrated submeter were provided by the manufacturers (ChargePoint Model CPH25, Juice Box Model Pro 40, and AeroVironment Model EVSE-RS) and were transported to an independent, third-party lab for testing (Eurofins / Met Laboratories).

A customized test plan was developed based off the ANSI C12.20 standards that were applicable to the charging stations. The utilities and Nexant designed the submeter accuracy tests included to test the submeter responses to three variables; varying input voltage to the charging stations, two levels of power factor (PF) for the AC power supply, and variable duration for the tests.

The tests were designed to represent some of the best and worst case power quality conditions (voltage and PF) a charging station in the field could be subject to as well as customer habits on charge duration. Due to delays created by technical challenges in setting up the test and registering the charging stations, the original slate of proposed tests was refined to focus on the following tests:

- **No Load Tests**
- **Full Load, Short Duration Tests**
  - 100% Load @ 240 V @ 100% PF for 5, 10, and 15 Minutes
  - 100% Load @ 240 V @ 50% PF for 5, 10, and 15 Minutes
  - 100% Load @ 250 V @ 100% PF for 5, 10, and 15 Minutes
  - 100% Load @ 250 V @ 50% PF for 5, 10, and 15 Minutes
  - 100% Load @ 230 V @ 100% PF for 5, 10, and 15 Minutes
  - 100% Load @ 230 V @ 50% PF for 5, 10, and 15 Minutes
  - 100% Load @ 220 V @ 100% PF for 5, 10, and 15 Minutes
  - 100% Load @ 220 V @ 50% PF for 5, 10, and 15 Minutes

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<sup>36</sup> For a primer on these methods, see Robinson, et al. (2005), "A regression-based equivalence test for model validation: shifting the burden of proof".

- **Light Load, Short Duration Tests**

- 1% Load @ 240 V @100% PF for 5, 10, and 15 Minutes
- 1% Load @ 250 V @100% PF for 5, 10, and 15 Minutes
- 1% Load @ 230 V @100% PF for 5, 10, and 15 Minutes
- 1% Load @ 220 V @100% PF for 5, 10, and 15 Minutes

- **Full Load, Long Duration Tests**

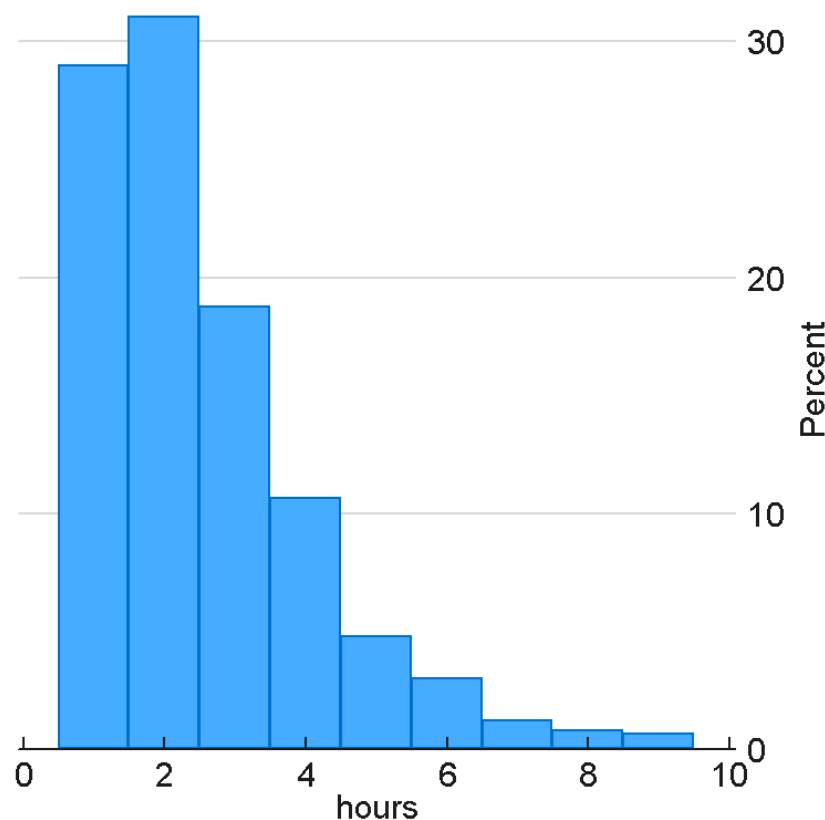
- 100% Load @ 250 V @100% PF for 3.5 hours
- 100% Load @ 250 V @ 50% PF for 3.5 hours
- 100% Load @ 220 V @ 100% PF for 3.5 hours
- 100% Load @ 220 V @ 50% PF for 3.5 hours

- **Light Load, Long Duration Tests**

- 1% Load @ 240 V @ 100% PF for 3.5 hours
- 1% Load @ 230 V @ 50% PF for 3.5 hours

The lab retained the second charging station from each manufacturer in case of operational problems with the first unit, or to confirm any extreme outlier results in the revised test plan. A histogram of the charging durations from the Phase 2 field logging, depicted in Figure 3-3, indicates that most charging cycles (approximately 90%) were completed in less than four (4) hours.

**Figure 3-3: Histogram of Charge Duration from Logged Data**



During the initial short duration testing of the ChargePoint CPH25 submeter, the lab found that a relay would open at 50% PF under full load disabling the charging station. Additional testing at incrementally higher PF values revealed that the minimum PF for which full load testing could be completed was 81%.

The test equipment used to measure the accuracy of the submeters is a Dytronic Reference Standard from Radian Research, Model Radian RD-20-203. According to the independent lab, the accuracy of this is the only relevant component in the test measurements; the Radian measures watt-hour accumulation for direct comparison with the registered watt-hour accumulation of the submeter as recorded in the associated smartphone app. As indicated on the calibration certification, the Radian's worst case error is 0.04%. In normal operation, this error is closer to 0.005%. The lab's Radian is calibrated annually, with the most recent calibration on July 18, 2018.

The laboratory used each submeter provider's online portal to access the kWh registers.<sup>37</sup> For eMotorWerks JuiceNet devices (JuiceBox and AeroVironment) the technician would go to the "History Tab" on the portal and take note of the initial kWh value before applying the load to the circuit. After the test, the technician would refresh the page and extract the final kWh value before turning off the charging station. When starting a new test, the technician would turn on the charging station and repeat the process. For the ChargePoint charging station the technician would perform the same tasks. On the portal, the technician would go to the "My Stats" tab and note the kWh before and after the test.

Results from the laboratory testing are summarized in Section 4.3.2, and a redacted version of the report is provided in Appendix G. The detailed results are redacted, but copies with viewable results were provided for review to each of the vendors who provided submeters for testing. The laboratory report also includes details regarding the specific equipment and setup used for testing.

### 3.3 Customer Experience

To evaluate the customer experience, a series of three web-based surveys were used to collect information on various aspects of the pilot. The Welcome Survey was sent near the beginning of Phase 2 of the pilot and included questions to determine motivations for signing up for submetering, knowledge of submetering processes, customer service, problems encountered, and whether or not customers were satisfied with their submetering service.

As is typical in survey-based research, modest incentives were provided to survey participants to compensate them for their time and to improve response rates. Participants were paid \$50 for the completion of two customer satisfaction/experience surveys; one in February/March 2017 (three months after the enrollment period begins), and a follow-up in January/February 2018 (shortly before the end of the pilot on April 30, 2018). Customers who agreed to install a data logger were paid \$150 upon collection of the equipment and data.

Following the Welcome Survey, Nexant sent a survey to customers who unenrolled from the pilot, did not complete enrolling in the pilot, or did not sign a CEA. For customers who unenrolled from the pilot, the survey included questions to determine motivations for signing up;

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<sup>37</sup> The submeter does not have a direct data access port. The only way to access the data is once it has been transmitted to the MDMA.

their level of satisfaction with the enrollment process; their motivations for un-enrolling; knowledge of submetering processes; customer service; problems encountered; and whether or not customers were satisfied with their submetering service.

Prospective customers—those who did not complete enrollment, or completed enrollment but did not sign a CEA—received a survey with questions to determine motivations for considering whether to sign up, and if applicable, their level of satisfaction with the enrollment process; their reasons for not completing enrollment; knowledge of submetering processes; customer service; and problems encountered. Lastly, Nexant sent a Post Pilot Survey to all remaining Phase 2 participants that had similar evaluation metrics as the Welcome Survey. The various topics that were covered in the Phase 2 pilot surveys are shown in Table 3-3.

**Table 3-3: Topics for Customer Experience Surveys**

Topic	Evaluation Metrics	Welcome Survey	Post Pilot	Unenrolled	Prospective
<b>PEV Characteristics</b>	Number of PEVs, make/model/year, miles driven per week, and charging details	✓	✓	✓	✓
<b>Motivations for Submetering</b>	Identify customer motivations to use PEV submetering	✓	✓	✓	✓
<b>Customer Knowledge</b>	Measure the level of customer understanding of the submetering processes and TOU rates	✓	✓		
<b>Customer Satisfaction</b>	Measure customer satisfaction with the enrollment process	✓	✓	✓	✓
	Measure customer satisfaction with the submetering services provided by MDMAs and utilities	✓	✓		
	Measure customer satisfaction with the pilot	✓	✓	✓	✓
<b>Issue Resolution</b>	Identify the number, frequency, and type of customer issues related to metering accuracy, data accessibility, and billing	✓	✓	✓	
	Evaluate ability of submeter MDMAs and utilities to resolve customer issues	✓	✓		

Because enrollment in Phase 2 was lower than the pilot caps, it was necessary to recruit as many customers as possible for the participant survey in order to obtain statistically valid results. To avoid overexposing participants to recruitment efforts for the different components of the pilot and achieve the high response rates needed for the analysis, recruitment activities for the participant Welcome Survey and accuracy assessment were conducted jointly.

### 3.3.1 Survey Implementation

#### 3.3.1.1 Welcome Survey

To announce the survey, Nexant sent a letter<sup>38</sup> to all Phase 2 pilot participants by U.S. Mail. In the June 2017 letter, Nexant invited Phase 2 participants to complete two surveys online—one immediately, and another in the fall of 2017 (the Post Pilot Survey)—about their experience in the pilot. Customers who completed the Welcome Survey received a \$25 check.

Because email addresses were available for all pilot participants, invitations containing links directing the participant to the survey were sent via email as a follow-up in a staggered manner as follows: 2 days after letter posting, 4 days after letter posting, and one week after letter posting. Ten days following the start of the survey recruitment process, Phase 2 pilot participants who had not yet completed the survey were mailed a paper copy of the instrument. Twenty days following the start of recruitment, the Nexant Survey Lab attempted to complete the survey with participants over the telephone.

Response rate varied across the three utilities, with the highest response rate at SCE (92%) and the lowest at SDG&E (81%). Table 3-4 presents a summary of participant survey response rates by utility.

**Table 3-4: Pilot Participant Survey Response Rates by Utility – Welcome Survey**

Utility	Surveys Sent	Surveys Completed	Response Rate
PG&E	240	200	83%
SCE	136	125	92%
SDG&E	58	47	81%
<b>Total</b>	<b>434</b>	<b>372</b>	<b>86%</b>

#### 3.3.1.2 Unenrolled and Prospective Participants Survey

Between the Welcome and Post Pilot Surveys, Nexant sent a survey to participants who unenrolled from the pilot, who did not finish the enrollment process, or who did not sign a CEA. The unenrolled and prospective participant survey was announced by a letter<sup>39</sup> delivered to the aforementioned customers by U.S. Mail. Nexant mailed the letter in August 2017 and invited the unenrolled and prospective pilot customers to complete the online survey about their experience in the enrollment process and/or pilot. Nexant informed customers that they would receive a \$25 check for completing the survey.

<sup>38</sup> The invitation letter contained CPUC and Nexant co-branding and signatures.

<sup>39</sup> The invitation letter contained CPUC and Nexant co-branding and signatures.

Unique survey links were created for unenrolled and prospective customers in the case that their MDMA was unwilling to share emails. The MDMA sent email invitations and limited follow up reminders to one in order to avoid pilot evaluation over-exposure. A total of 200 customers were identified as prospects by the MDMA, 63 of which responded to the prospect survey.

A total of 14 surveys were sent to customers who did not sign a CEA. The majority of the surveys were sent to PG&E customers, and almost half (44%) of incomplete applicants responded. Table 3-5 presents a summary of incomplete application survey response rates by utility.

**Table 3-5: Pilot Participant Survey Response Rates by Utility – Incompletes**

Utility	Surveys Sent	Surveys Completed	Response Rate
PG&E	9	4	44%
SCE	4	0	0%
SDG&E	1	0	0%
<b>Total</b>	<b>14</b>	<b>4</b>	<b>29%</b>

Nexant sent a total of 20 surveys to customers who unenrolled. Table 3-6 presents a summary of incomplete application survey response rates by utility.<sup>40</sup>

**Table 3-6: Pilot Participant Survey Response Rates by Utility – Unenrolled**

Utility	Surveys Sent	Surveys Completed	Response Rate
PG&E	17	9	53%
SCE	0	0	0%
SDG&E	3	1	33%
<b>Total</b>	<b>20</b>	<b>10</b>	<b>50%</b>

### 3.3.1.3 Post Pilot Survey

The Post Pilot Survey followed the same recruitment strategy as the Welcome, and unenrolled and prospective surveys. We announced the survey with a May 2018 letter<sup>41</sup> delivered to all Phase 2 pilot participants by U.S. Mail. Customers were informed that they would receive a \$25 check for completing the survey.

Invitations containing links directing the participant to the survey were sent via email as a follow-up in a staggered manor as follows: 2 days after letter posting, 4 days after letter posting, and one week after letter posting. Twenty days following the start of recruitment, the Nexant Survey Lab attempted to complete the survey with participants over the telephone.

Response rates varied across the three utilities, with the highest response rate at SCE (88%), followed by PG&E (78%), and SDG&E (67%). Response rates declined for all utilities with the

<sup>40</sup> Subsequent to the surveys being sent, additional customers unenrolled. This group was composed of 36 PG&E customers, 6 SCE customers and no SDG&E customers.

<sup>41</sup> The invitation letter contained CPUC and Nexant co-branding and signatures.

Welcome Survey for SDG&E having the largest percentage point decrease (14%), followed by PG&E (5%), and SCE (4%). Table 3-7 presents a summary of participant survey response rates by utility.

**Table 3-7: Pilot Participant Survey Response Rates by Utility – Post Pilot Survey**

Utility	Surveys Sent	Surveys Completed	Response Rate
PG&E	204	160	78%
SCE	130	115	88%
SDG&E	58	39	67%
<b>Total</b>	<b>392</b>	<b>314</b>	<b>80%</b>

## 4 Results

Phase 2 produced a large amount of primary data to investigate the research questions described in Sections 2 and Section 3. This section presents and discusses the results for each of the four primary components of the evaluation.

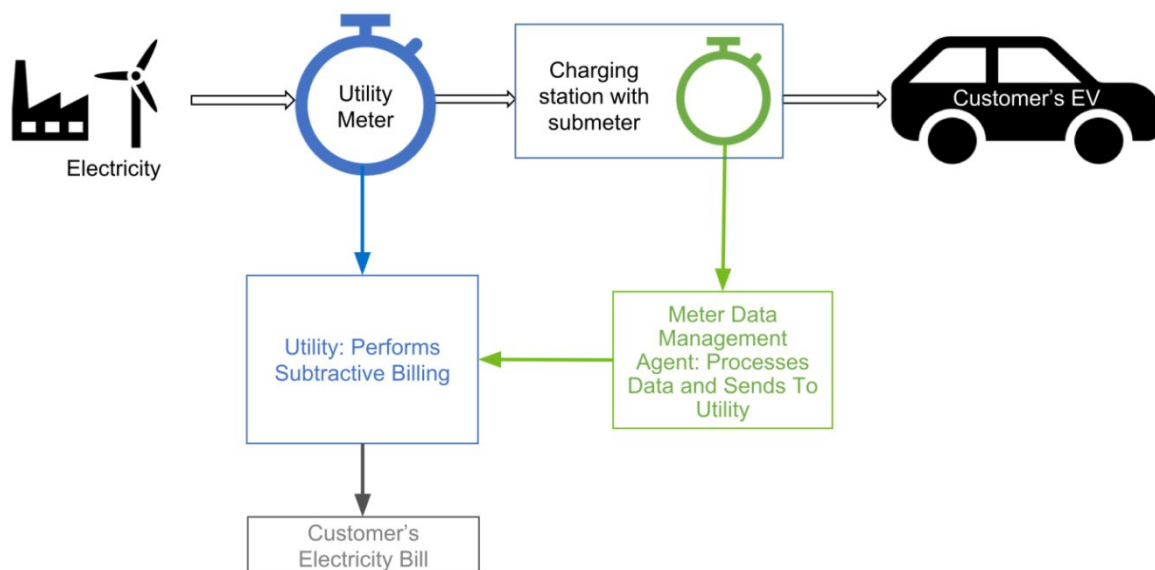
### 4.1 Service Offerings and Business Processes

A crucial part of evaluating potential business models and opportunities was to understand the relationships between each stakeholder, and identify potential incentive structures. Figure 4-1 depicts these relationships for Phase 2 of the pilot in which a SCOR was responsible for paying for all of the electricity consumption at a premise.<sup>42</sup>

Participating customers in Phase 2 were almost entirely residential customers living in a single family home. The one exception was a condominium homeowners association (billed at a commercial rate) that registered as a multi-family SCOR customer. This case was not included in the logger-based accuracy study but was included in the customer surveys and other portions of the study.

Electricity consumption data at a premise with submetering comes from two sources—the submeter and the primary meter. The primary meter tracks all power consumption by the customer including PEV charging, while the submeter measures only the power used by the charging station. Figure 4-1 reviews the relationships between the customer, the MDMA and the utilities.

**Figure 4-1: Activities and Responsibilities for Submetering Stakeholders in Phase 2**



<sup>42</sup> Master metered premises were not eligible for Phase 1 of the pilot.

It is possible to have a PEV enrolled on a TOU rate and the rest of the home on a different rate without submetering; however, this requires customers to install a second utility-grade meter, which can cost at least \$2,000, depending on the complexity of the installation.<sup>43</sup> Because of this high cost, enrollment in separately metered rates has been low. According to the utilities, most PEV customers choose one of two options for paying for their charging at home:

- Remain on the same rate as before acquiring a PEV (typically a tiered rate).<sup>44</sup>
- Enroll on a TOU rate that applies to the entire home (including the PEV).
- Enroll on a PEV-specific TOU rate that applies to the entire home and offers a lower off-peak rate than traditional TOU rates (e.g., PG&E's EV-B).

A tiered rate plan, which is currently the default rate for residential customers in California, is based on overall consumption per billing cycle. Under this rate schedule customers are allotted a certain amount of “baseline” power at the lowest available rate per kWh. This rate is applied to roughly the first 50% of average electricity consumption for customers in a particular baseline territory (related to climate zone).

Once a customer consumes more than the baseline allocation they then enter Tier 2 and their rate for electricity consumed in this tier is significantly higher and all of the electricity they now consume is charged at this higher rate. If consumption exceeds the Tier 2 allocation, then the customer is subject to an even higher high-usage surcharge rate. For PEV users, the disadvantage of a tiered rate is that PEV charging will likely push them from Tier 1 to Tier 2, or in some cases, into a high usage surcharge rate and thus lead to a significantly higher overall power bill.

A whole-house TOU rate varies the price a customer pays depending on the time of day and season that a customer consumes power. TOU takes into account grid conditions, cost of using electricity at different times of day, and plentiful solar produced in the middle of the day.

This approach, which will become the default standard across California in 2019, is more complicated for consumers, but offers savvy users the opportunity to save money on electricity if they change the time of day at which they use electricity. TOU rate plans do this by providing customers with lower rates during off-peak hours (typically 9:00 PM to 8:00 AM the next day). By better aligning consumption with the times of day when power is most available, the TOU rate provides benefits to the power system. This approach can be beneficial to PEV users who are willing to charge their vehicles during off-peak hours.

Separately metering and submetering provide a third approach that allows the PEV's load to be segregated from the whole-house consumption. These approaches allow utilities to provide a preferential rate for PEV charging that is not tied to the household rate, and promotes off-peak charging for the PEV, and has the potential to save the customer on their bills.

However, the challenges of the submetering approach are the complexity of administering the program, and the related cost of implementation. In a scenario where PEVs become a

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<sup>43</sup> This cost likely varies substantially for different customers, but includes the cost of the meter itself, all applicable permits, compliance with electrical codes and the labor costs associated with installation.

<sup>44</sup> Customers who stay on a tiered rate do not have any incentive to charge during off-peak hours. This could result in local grid reliability issues if enough PEVs are charged on-peak.

substantial source of customer demand, charging without providing price signals to drive charging demand to off-peak hours could negatively affect grid stability.

#### 4.1.1 Technology Development

A prerequisite for providing submetering service is having a submetering product available for customers to install that is low-cost, safe, and reliable. All hardware for the pilot was required to be certified to Underwriter Laboratory (UL) standards to ensure safety of customers, installers, and the grid. Although the situation is changing rapidly, at the outset of Phase 2 UL-certified submeters for PEV charging were not widely available.<sup>45</sup>

##### 4.1.1.1 eMotorWerks

eMotorWerks recently acquired by Enel S.p.A., is a company based in San Carlos, California that operates a network of distributed load control devices used to provide grid stabilization services. The company's current offerings include PEV charging stations with grid management and user-facing control features that are managed through a proprietary cloud-based platform, JuiceNet. The grid management services provided by eMotorWerks include demand response, peak shaving, and local load balancing to help utilities and ISOs better manage the grid volatility and increased PEV adoption.

Through a successful Kickstarter campaign, eMotorWerks created the JuiceBox™, a Level 2 charging station with an integrated submeter. The JuiceBox is capable of up to 10kW and 40 Amp output with Wi-Fi remote telemetry, direct user controls, and advanced smart grid optimization features. eMotorWerks participated in both submetering pilot phases. In Phase 1 eMotorWerks was the primary hardware provider, directly or in partnership with demand response provider OhmConnect, via a stand-alone submeter connected to its cloud platform. In Phase 2, eMotorWerks partnered with AeroVironment to deploy the charging station-RE JuiceNet-edition to participants. Very late in Phase 2, the JuiceBox received its UL-certification and pilot authorization, and customers bought a small number towards the end of the pilot.

##### 4.1.1.2 ChargePoint

ChargePoint, Inc. is a privately held company based in Campbell, California that operates an open PEV charging network. ChargePoint engineers, designs, manufactures, and provides support for the PEV charging hardware, as well as engineering and maintaining a cloud-based network solution that enables energy management, payment processing, and driver support for users. ChargePoint serves nearly every segment of the PEV charging market: residential, multifamily, workplaces, fleets, utilities, municipalities, retail, transportation network companies (such as Uber and Lyft), medium duty and heavy-duty transportation, and parking service providers worldwide.<sup>46</sup> ChargePoint has developed their own in-house charging station with an integrated submeter.

##### 4.1.1.3 Kitu

Kitu Systems provides scalable internet of things (IoT) software, platforms, and applications connecting intelligent energy. Their solutions serve markets such as PEV charge management, distributed energy control and monitoring (solar, wind or battery), smart appliances, and load

<sup>45</sup> eMotorWerks used AeroVironment charging stations because the JuiceBox was not UL certified. The JuiceBox was finally UL certified in the final months of the pilot and eMotorWerks requested permission to replace any broken AeroVironment submeters with JuiceBoxes.

<sup>46</sup> Source: <https://www.bloomberg.com/profiles/companies/0288372Z:US-chargepoint-inc> and Wikipedia.

management. Their customers include utilities, enterprises, smart device manufacturers, and automotive companies. Kitu Systems has a long history of working with Webasto, formerly AeroVironment, and integrated their submeter-equipped charging stations into various energy management solutions for the home or the grid.

#### 4.1.2 Pilot Enrollment and Establishing Submeter Service

Participants enrolled in the pilot through the MDMAs who created small-scale marketing campaigns and offered customer-facing materials to explain the benefits of the program. To enroll, customers were required to fill out a CEA<sup>47</sup> with their MDMA who would submit it to the utility and facilitate submeter installation.

ChargePoint conducted a marketing campaign through Facebook and their current customer base emailing. Their ads received approximately 15,000-20,000 click-throughs that led customers to a landing page about the pilot and about 1,000 people filled out a lead form, indicating their interest in the pilot. Of those 1,000 there was about a 13.6% conversion rate to completed enrollment forms. Following their marketing to new customers, ChargePoint began marketing the pilot to existing customers through monthly newsletters and through the ChargePoint app.

eMotorWerks leveraged their email newsletter database of approximately 1,500 contacts and included a landing page and web form for pilot interest sign-up that offered customers incentives in the form of discounted charging stations. eMotorWerks did not conduct any other marketing aside from the landing page and email campaign—customers organically found them from web searches or from their utility's website.

As customers became aware of the pilot through the MDMA's marketing efforts, interested customers would contact an MDMA and create an online account with the MDMA.<sup>48</sup> After this electronic sign-up, prospective participants went through a pre-qualification check to make sure that they met the pilot eligibility criteria and could have a submeter successfully installed at their premise. Once this sign-up was completed and a customer purchased a submeter, the MDMA arranged a submeter installation appointment and emailed the customer a blank CEA to complete.

After having their charging station with submeter installed by a California licensed contractor, customers formally enrolled in the pilot by completing a CEA with assistance from the MDMA, who submitted them to the appropriate utility for approval. The MDMA submitted applications to the utilities via email as scanned PDF documents. The utilities reviewed the completed CEAs and communicated any problems/issues back to the customer and/or the MDMA.

To be eligible to participate in the pilot, customers were required to meet the following criteria:

- Have an active service account with their utility.
- Have an eligible interval data recorder meter (i.e., smart meter provided by their utility).
- Charge a PEV at their account.

<sup>47</sup> CEAs were similar for each utility and contained the terms and conditions of the pilot, a list of eligibility criteria, a description of the duties and obligations of the participant and utility and a form to provide information related to the submeter. CEAs could be rejected by the utility if customers did not meet the eligibility criteria or if the CEA contained any missing, incorrect, or crossed-out information. CEAs with issues were sent to the MDMA for resolution with the customer.

<sup>48</sup> This step was not necessary for existing eMotorWerks customers.

- Have an approved submeter installed for the exclusive use of tracking the energy used to charge the customer's PEV.
- Be a bundled service customer or community choice aggregation (CCA) customer.
- Not participate in any utility automatic payment plan options.<sup>49</sup>
- Not participate in the California Independent System Operator (CAISO)-sponsored demand response programs facilitated through Electric Rule 24.

During Phase 1 utilities had to send back submitted CEAs to customers for revisions, sometimes multiple times,<sup>50</sup> because they were incomplete or required corrections to minor issues such as improper address abbreviations, using shortened versions of a customer's name (e.g., "Bill" rather than "William"), or not submitting the pages of the CEA containing the terms and conditions, liability waiver, warranty disclaimer, etc., that did not require explicit responses from the customer. These errors occurred in spite of training that was provided to the MDMAs by the utilities to help guide the completion of the CEAs. Resubmitting CEAs required additional back and forth between MDMAs, customers, and the utilities.

In Phase 2, the utilities streamlined the enrollment process by simplifying the CEA and accepting CEAs with minor errors that could be corrected by the utilities. The major source of enrollment issues in Phase 2 centered around restrictions on what customers could participate. Customers who were enrolled in demand response programs were ineligible for participation in the pilot, and those who wanted to participate had to withdraw from any other demand response programs. The challenge here was that these demand response programs are often administered by third-party companies and thus the utilities could not remove customers from these programs. Customers were required to contact the program provider, withdraw from the prohibited program, and then resubmit their customer applications.

The enrollment period for Phase 2 began on January 16, 2017, and the pilot ended by April 30, 2018 for most customers.<sup>51</sup> Enrollment was capped at 500 submeters per utility, including a limit of 100 submeters per utility for which the customer of record is also a NEM customer. MCOR customers were limited to 19 submeters per primary meter, and each submeter would count individually towards the 500 cap. However, as previously mentioned, no MCOR customers participated in the pilot. One MDMA indicated they were not able to enroll MCOR customers because there was not enough time to initiate this enrollment process within the time frame of the study. The challenge, from a program implementation perspective, is that in MCOR settings a property manager or home owner's association must provide approval for the installation of a charging station. This approval process can take much longer than a typical residential customer making a participation decision.

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<sup>49</sup> These include the "Balance Payment Plan" or "Automatic Payment Plan" options offered by PG&E, the "Level Pay Plan" or "Direct Pay Plan" options offered by SCE and the "Level Pay Plan" or "Online Automatic Payment" options offered by SDG&E. Customers who were enrolled in any of these programs could de-enroll temporarily in order to participate in the pilot.

<sup>50</sup> 56 of the 92 customer agreements for SCE needed to be resubmitted by the MDMA.

<sup>51</sup> The exact timing of when a customer's pilot ended varied because the study lasted for 12 monthly billing cycles from the date of enrollment. The exact date of un-enrollment was dependent on when they enrolled in the program, and their billing cycle date within the month.

Total participation at the end of the enrollment period consisted of 449 submeters—240 at PG&E, 151 at SCE, and 58 at SDG&E. The majority of participating customers enrolled through either ChargePoint (377) or eMotorWerks (69). Only 3 customers enrolled via Kitu Systems.

Phase 2 enrollment is summarized in Table 4-1, which also includes the submeter rates that are available to pilot participants in each territory. The maximum duration for participation in Phase 2 was 12 billing cycles, and customers were allowed to withdraw from the pilot at any time.<sup>52</sup>

**Table 4-1: Phase 2 Enrollment by Submeter**

Utility	Total Enrollment	Submeters by MDMA		Submeter Rate for Residential Pilot Participants	
		ChargePoint	eMotorWerks	Kitu	
PG&E	240	197	41	2	EV-B (Residential) \$20 bill credit (Commercial)
SCE	151	130	20	1	TOU-EV-1 (Residential) <sup>53</sup>
SDG&E	58	50	8	0	EV-TOU (Residential) \$20 bill credit (Commercial)
<b>Total</b>	<b>449</b>	<b>377</b>	<b>69</b>	<b>3</b>	

### 4.1.3 Data Transfer and Subtractive Billing

To become an official MDMA in Phase 2 of the pilot, the MDMAs were required to go through testing with each of the three utilities to demonstrate their ability to deliver data in a format that could be used for billing. Data transfer protocols during the testing phase mirrored the actual data transfer process in many respects. Individual data files were sent for each customer via secure file transfer protocol (SFTP) containing usage data for the submeter in 15-minute intervals, along with a unique universal ID number attached to every interval.<sup>54</sup>

Upon enrollment of the customers, the MDMAs began sending submeter data to the utilities on a daily or near-daily basis. The utilities, at their own discretion, may elect to inspect the data to verify it was in the correct format and not missing any intervals. In the event that any issues were discovered, the utilities may provide the MDMA with an exception notice describing the problem and work with them to find a solution in order to improve customer satisfaction. Completed CEAs also established an official pilot “start date” for each customer based on the beginning of their next individual billing cycle. Because enrollments occurred in the middle of billing cycles, customers received their first bill containing the submeter usage after completing their first full bill cycle in the pilot.<sup>55</sup> Launching a subtractive billing process was an upfront investment in Phase 1 for each utility that was not built into existing billing processes for practical reasons.<sup>56</sup>

<sup>52</sup> At the end of the pilot 36 PG&E participants, and 66 SCE participants had withdrawn from the pilot.

<sup>53</sup> SCE had multiple TOU rates available for commercial customers.

<sup>54</sup> UUIDs were used at SCE and SDG&E. This requirement was relaxed at PG&E.

<sup>55</sup> For example, if a customer’s CEA was accepted on July 21 and their current bill cycle ended on July 29, then the first bill that included submetering would not be sent until after the following bill cycle (e.g. July 29-August 31).

<sup>56</sup> As stated in R.09-08-009, “Prior to making significant capital upgrades to the utility billing process, the Commission wants to understand the demand for submetering, evaluate the costs of a billing system, and determine how that cost will be assigned.”

As a result, each utility developed different processes to incorporate submetered data into the core billing system. Given the uniqueness of each utility's billing system, each utility implemented different solutions with varying degrees of automation, but a common experience was the need to educate MDMAs about how the billing process works,<sup>57</sup> and the associated data requirements. Appendix E contains process flow documents utilized by one of the utilities. The following sub-sections detail the experience of each utility in performing subtractive billing during Phase 2.

#### 4.1.3.1 PG&E

PG&E leveraged a feature of their customer information system (CIS) as the basis for designing a new computer program to perform subtractive billing calculations.<sup>58</sup> The new routine involved several manual steps that were outside normal billing operations, including the subtraction itself, which was done for every 15-minute interval. Performing subtractive billing at the 15-minute interval level required the data for all intervals to be in the same format,<sup>59</sup> which required additional data validation steps for both the submeter data provided by the MDMA, and interval data from PG&E's meter data management system.

The construction of the subtractive billing process was an iterative effort that required fixes early on in the pilot to address data issues that were uncovered. During Phase 1 of the pilot PG&E was able to provide ad hoc automation to several steps of the process to improve speed and reliability, but some steps remained mostly manual—e.g., dealing with estimated meter reads in whole-house data. In Phase 2 of the pilot PG&E removed the requirement to use unique user IDs (UUIDs) in order to streamline the data transfer process.

The semi-automated processes were applicable to the small scale of the pilot, but none of the processes are scalable, which is why they would need to redesign the billing systems to further improve the reliability of the subtractive billing process. PG&E stated the level of automation was 0% based on automation meaning the ability of the billing process that could be scaled to full scale deployment.

#### 4.1.3.2 SCE

Similar to PG&E, subtractive billing was an entirely new process for SCE. This involved software changes within SCE's data system and manually setting up a new account for each pilot participant to manage PEV submeter usage and whole-house usage separately. While much of the data management was able to be automated, the subtractive billing process itself was still performed manually by a member of the project team. SCE estimated that 20% of their processes were automated and 80% were manual during the pilot.

#### 4.1.3.3 SDG&E

Unlike PG&E and SCE, SDG&E had some previous experience with submetered PEVs prior to the pilot, from another pilot that was conducted for estimating the impacts of TOU pricing on

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<sup>57</sup> This included the timing of when customers would receive their first submetered bill, helping customers understand what rate they were on and whether changes were being made to their account, specific data formatting necessary to integrate with utility billing systems, electronic vs. paper bills, etc.

<sup>58</sup> The referenced CIS feature had previously been used only with monthly data, not 15-minute interval data.

<sup>59</sup> This was an issue for the small percentage of intervals from PG&E smart meters that contain estimated meter reads for the whole-house as well as any missing submeter reads.

PEV charging behavior.<sup>60</sup> The key Phase 2 development work that was needed consisted of adapting the existing system to incorporate the data stream from the MDMAs. During Phase 1 the process was approximately 10% automated and 90% manual. Data received from the MDMAs was not integrated into SDG&E's other data systems—per the rules of the pilot—and was therefore stored on a separate server from the whole-house data recorded by SDG&E's smart meters. During Phase 2, SDG&E rebuilt the process so that it was approximately 90% automated and only 10% manual. The subtractive billing calculation itself was automated and entered manually by a member of the SDG&E pilot team based on the end dates of the customers' billing cycles.

## 4.2 Demand for Submetering

In Phase 1 of the pilot Nexant administered a survey aimed at assessing the demand for submetering among current PEV owners who were not part of the submetering pilot. Because this survey was not rerun as part of Phase 2, and because the Phase 1 results may help inform the development of a submetering protocol, we briefly summarize the results in this section.

This survey design evaluated respondent preferences for different service offerings. Respondents who did not own a PEV at the time of the study or who never charged at home were disqualified, as were respondents who did not finish the survey. In order to ensure that responses were indicative of the preferences for the average PEV owner in California, responses were weighted to reflect the residential customer population within each utility territory. A full explanation of the sampling strategy and survey methodology is in Section 3.4 of the Phase 1 report; available online at:

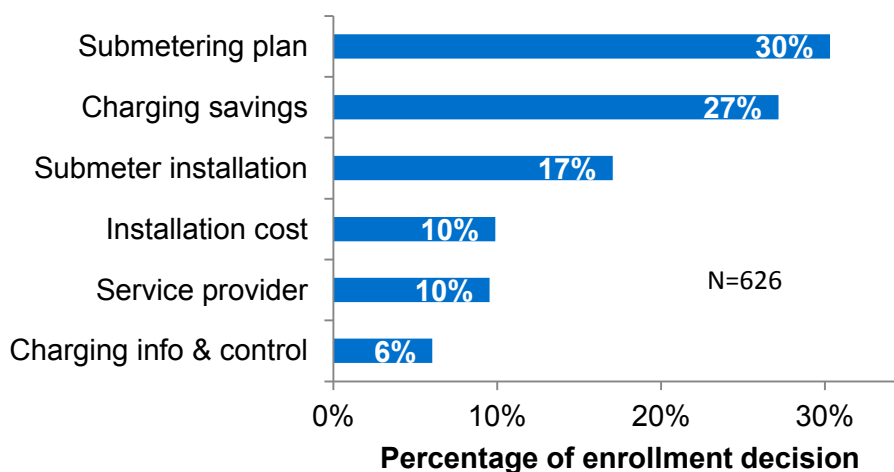
<http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453395>

The key finding from this survey was that 41% of PEV owners in 2016 said that they would be willing to enroll in a submetering system program similar to the Phase 1 pilot. Survey questions of this kind are often subject to a positive hypothetical bias—in other words, respondents can overstate their likelihood of signing up for a future program. However, even with this bias noted, this survey shows that there's strong interest in using submetering to save money on PEV charging.

The most important factors driving customer interest in submetering were saving money on charging, and saving money on the purchase and installation of a home charging station. We remind the reader that this result was from a conjoint adaptive survey that did not specify precise incentives. Figure 4-2 shows the relative importance of the attributes from the survey.

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<sup>60</sup> See "Final Evaluation for San Diego Gas & Electric's Plug-in Electric Vehicle TOU Pricing and Technology Study" (2014): <https://www.sdge.com/sites/default/files/documents/1681437983/SDGE%20EV%20%20Pricing%20%26%20Tech%20Study.pdf>

**Figure 4-2: Relative Attribute Importance**

For better understanding of the extent to which enrollment would be changed by altering the economics of submetering plans, the conjoint adaptive study included charging savings and submeter installation costs as attributes to be tested in the study. Figure 4-3 summarizes these attributes and levels, along with the modeled relative enrollment impact each level would have as compared to the levels comprising a prototypical program design similar to those offered in Phase 1 of the pilot.

**Figure 4-3: Relative Impact on Enrollment Compared to Pilot: Financial Attributes**

Installation cost	None [pilot]	
	\$150 (or \$3/mo for 60 months)	-34%
	\$300 (or \$6/mo for 60 months)	-49%
Charging savings (%)	16%	-2%
	30% [pilot]	
	45%	+54%
	60%	+80%
	81%	+103%

Based on the survey results, and assuming all other attributes are held equal, passing \$150 of installation costs to participants will reduce enrollment by over a third (34%), and passing on \$300 of these costs will cut enrollment in half. On the other hand, higher levels of charging savings, beyond the 30% in the description of the pilot, generated increasing interest in the program. These values were hypothetical numbers presented in the context of the conjoint survey.

Another goal of the survey research was to gain a better understanding of which potential future business models and features for submetering plans could increase appeal to PEV owners. To address this research question Nexant tested four attributes relating to participant experience—plan type, charging information and control, service provider, and submetering installation.

Figure 4-4 on the following page summarizes these attributes and levels, along with the modeled relative enrollment impact each level would have compared to the corresponding levels of a prototypical submetering similar to Phase 1.

The submetering plan attribute was intended to test the openness of PEV owners to different possible submetering business models. In particular, it tested a flat monthly charging fee—which may include charging on a network of public chargers for no extra cost—and a discounted rate that may include a higher discount in return for grid services through demand response.

Before answering these questions, respondents were carefully educated on the concept of grid services before the conjoint survey, and an option was only included for respondents who indicated they might consider it. The Phase 1 submetering plan, which simply includes access to a discounted rate, was largely preferred. However, the preference against the other submetering models was small enough that it could be addressed by designing a plan with other more desirable options to counterbalance the enrollment impacts.

**Figure 4-4: Relative Impact on Enrollment Compared to Phase 1: Business Model and Participant Experience Attributes**

Submetering plan	Flat monthly fee (charge anywhere)	-26%	
	Flat monthly fee (charge at home)	-18%	
	Electricity discount [pilot]		
	Electricity discount + grid services	-28%	
Charging info & control	Bill only	-12%	
	Info [pilot]		
	Info + con  (Ctrl) ▾		+12%
Service provider	Utility [logo shown]		+48%
	Car brand name [logo shown]		+18%
	Independent EV charging company [pilot]		
Submeter installation	Simply plug-in		+23%
	Mobile (in-car)		+32%
	Meter (pro-install) [pilot]		
	Pro + level 2 charger [Add \$600]	-23%	

From a review of Figure 4-4 we can see that under a Submetering plan respondents were most attracted to a discounted rate, which was provided by Phase 1 of the pilot. Offering charging anywhere, or at home, for a flat monthly fee were both seen as preferable alternatives—hence driving a decrease in the likelihood of enrolling in a submetering plan. Among respondents who were open to grid services, modeled enrollment actually increased by 6% by moving to that design and holding all other attributes equal to those in the pilot.

Service provider and submeter installation attributes were the biggest drivers of relative increases in enrollment. The three levels tested for the Service provider attribute were the respondent's utility, the respondent's PEV manufacturer (both of which were displayed using logos) and an independent PEV charging company (e.g., the vendors in Phase 1). Utility and PEV manufacturers were preferred to independent charging companies as service providers, and most respondents largely preferred a utility service provider to a PEV manufacturer.

The two other submeter installation options tested were simply plug-in and mobile submetering, which are not currently widely available. Both of these features were positively perceived by respondents and could increase enrollment by 23% and 32%, respectively.

## 4.3 Accuracy of Submeter

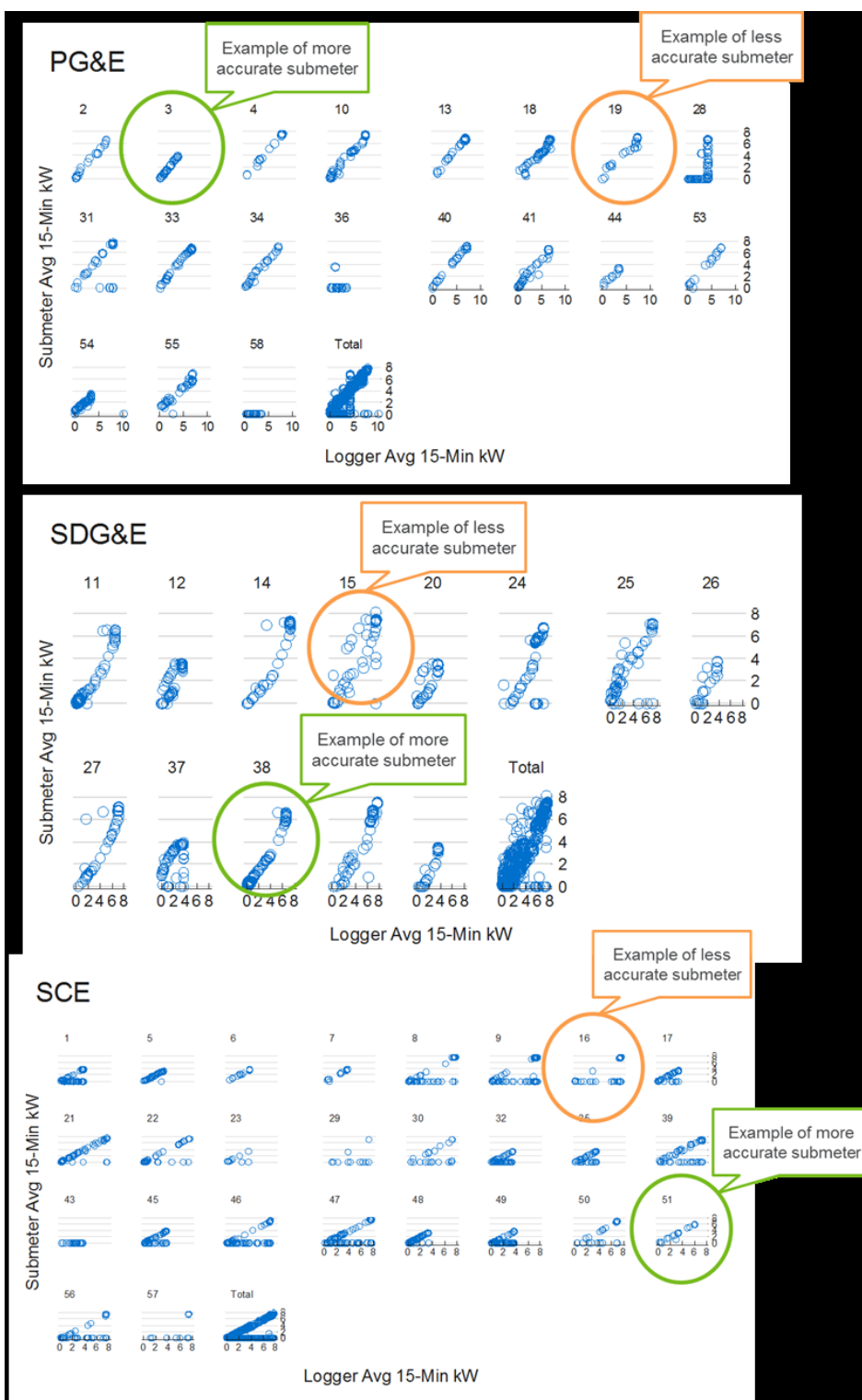
### 4.3.1 Nexant Analysis

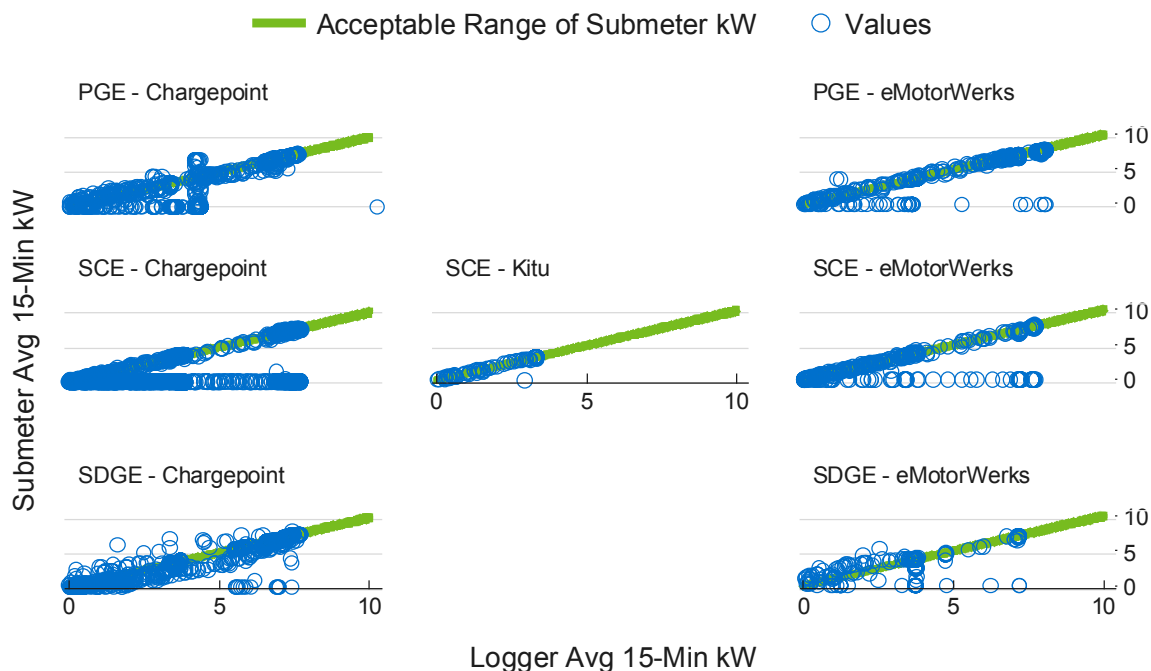
#### 4.3.1.1 Accuracy

In order for submetering to be successful from both a business and customer satisfaction perspective, submeters must be able to provide accurate measurements of PEV charging. As part of Phase 2 Nexant installed data loggers to independently measure PEV charging loads. Loggers were installed at 58 submeters on customer premises for the period August 5th, 2017 through September 13th, 2017. The sample included 40 submeters provided by ChargePoint, 17 provided by eMotorWerks, and one supplied by Kitu.

We began the accuracy analysis by visually investigating the differences between the submeters and the data loggers in each 15-minute interval. For intervals where charging usage was greater than zero according to the logger, submeter measurements were directly compared to logger readings. Figure 4-5 and Figure 4-6 on the following pages show the comparisons for each submeter in the form of scatter plots by utility, and by utility and MDMA. Each 15-minute interval is represented in the figure by a blue circle. When submeters and loggers agree, these graphs will show a straight 45-degree line. Deviations from the 45 degree line represent inaccuracies. The Y-axis in the graphs represent the submeter average 15-minute kW, and the X-axis represents the logger readings for the same time interval. As you can see, there are instances in this data that are not on the 45 degree line for a number of customers at each utility. For example, see PG&E logger 19, SDG&E logger 15, and SCE logger 16.

Figure 4-5: Submeter Measurements vs. Logger Readings by Utility



**Figure 4-6: Submeter Measurements vs. Logger Readings by Utility and MDMA**

Failures by type for each customer were documented to assess the frequency of each failure type. Failure types were classified into:

- **Time Shifting Issues**, which occurred when the timing of a submeter's charging information did not match the timing of the logger or the whole-house consumption.
- **Recording Issues**, which occurred when a submeter did not record an instance of charging.
- **Magnitude Issues**, which occurred when the magnitude of the charging load recorded by the submeter did not match the magnitude of the charging load recorded by the logger.

Counts by failure type are presented in Table 4-2<sup>61</sup>. The instance of a logger reading greater than its corresponding submeter was most common, followed by the submeter failing to record an instance of charging. Logger usage measurements are expected to be greater than submeter usage measurements in some cases because of line losses between the location of the logger and the location of the submeter on the circuit. Note that customers could have multiple failure types. Visualization of time shifting, recording, and magnitude issues are presented in Figure 4-7, Figure 4-8, and Figure 4-9 respectively.

<sup>61</sup> Counts for this table were visual observations and may not always exceed the 2% threshold difference. Therefore, the counts in this table may differ from Table 4-3.

Table 4-2: Failure Modes by Utility and MDMA

		Customer Count	Time Shifting Issues		Recording Issues			Magnitude Issues		Summary	
			Irreconcilable Timeshift	+/- 15 Minute Timeshift	Submeter Failed to Record Any Charging	Submeter Failed to Record an Instance of Charging	Logger Failed to Record	Logger Magnitude > Submeter	Submeter Magnitude > Logger	Count of Issues	Issue Density
PG&E	ChargePoint	11	1		1			3		4	36%
	Kitu	0								0	0%
	Emotorwerks	8	1			1		5		6	75%
	Total	19	2	0	1	1	0	8	0	10	53%
SCE	ChargePoint	18	2	8	1	10	1	5		25	139%
	Kitu	1						1		1	100%
	Emotorwerks	7				4		6		10	143%
	Total	26	2	8	1	14	1	12	0	36	138%
SDG&E	ChargePoint	11		1		1		8		10	91%
	Kitu	0								0	0%
	Emotorwerks	2				2		1		3	150%
	Total	13	0	1	0	3	0	9	0	13	100%
Total	Total	58	4	9	2	18	1	29	0	59	102%

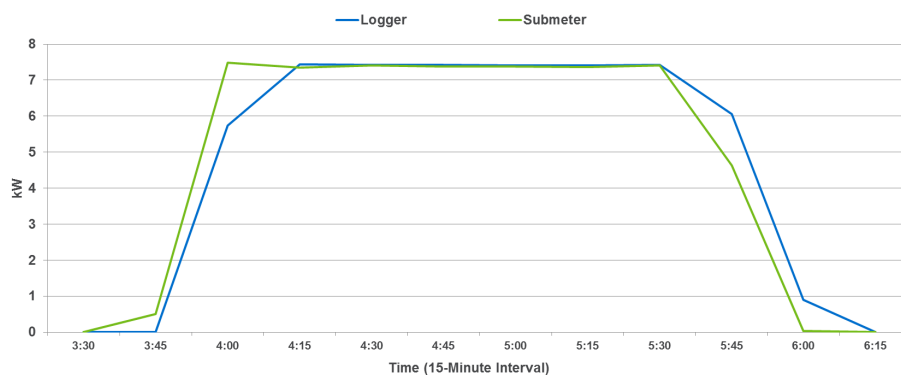
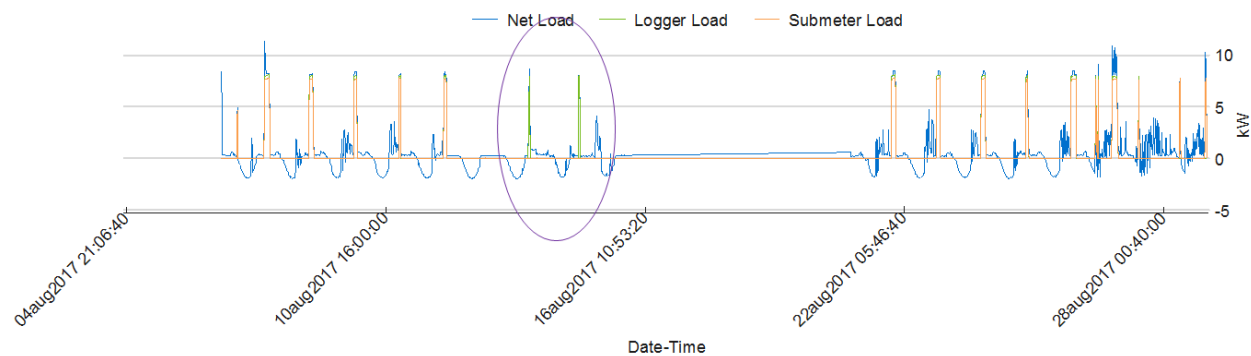
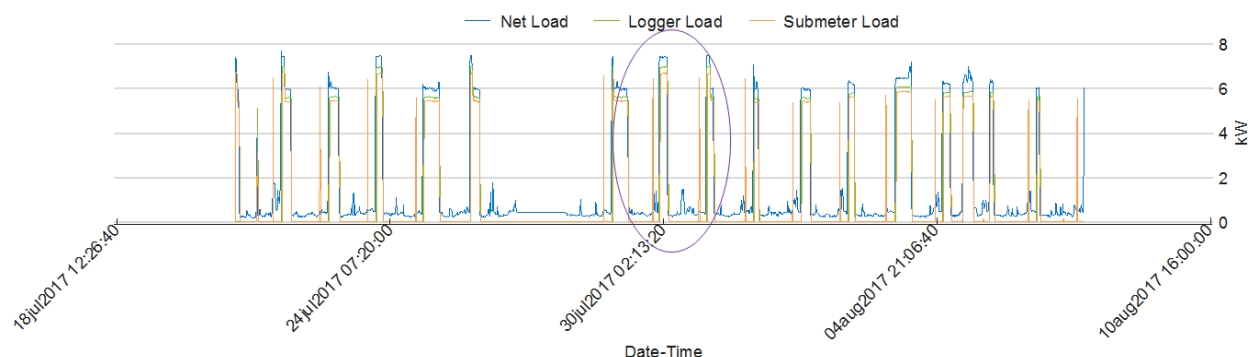
Figure 4-7: Time Shift in Data<sup>62</sup>

Figure 4-8: Submeter not Recording Instance of Charging



<sup>62</sup> In this example, we see the submeter is showing charging starting a full 15 minutes sooner than the logger and the logger is showing usage 15 minutes after the submeter indicates the charging has ceased.

**Figure 4-9: Submeter Magnitude Lower than Logger and Time Shifts**

To formally test the similarities between the submeter measurements and logger readings, an equivalence testing approach with a threshold of 2% (see Section 3.2) was used in two distinct ways. The first was to use a paired t-test approach. A paired t-test is a statistical test used to compare the means of two different samples, where observations in one sample are paired with observations in a second sample. This approach consists of two separate tests, one of the null hypothesis that the submeter mean is at least 2% less than the logger mean, and the second of the null hypothesis that the submeter mean is at least 2% greater than the logger mean. The results of the equivalence tests for each submeter are shown in Table 4-3 on the following page.

About 95% of the submeters failed to meet the  $\pm 2\%$  accuracy required field accuracy at some point during the observation period when evaluating accuracy at the 15-minute level. In order to determine if the submeters were reasonably close to the target, the analysis was repeated using daily consumption levels rather than the 15-minute level. This relaxed constraint allows for minor deviations between 15-minute intervals to net-out on a daily basis. At the daily level, more than 90% of the submeters failed at  $\pm 2\%$  threshold. Only at daily kWh levels with a tolerance of  $\pm 5\%$  (the accuracy standard used Phase 1) did approximately 19% of the submeters pass.

In summary, the submeters failed to provide the accuracy necessary for utility billing requirements established in this pilot.

**Table 4-3: Equivalence Testing Results**

% of Customers Passing (15-minute kW Intervals, with +/- 2% Threshold)				
	PG&E	SCE	SDG&E	Total
Chargepoint	0.0%	0.0%	0.0%	0.0%
Kitu		0.0%		0.0%
eMotorWerks	37.5%	0.0%	0.0%	17.6%
Total	15.8%	0.0%	0.0%	5.2%

% of Customers Passing (Daily kWh Intervals, with +/- 2% Threshold)				
	PG&E	SCE	SDG&E	Total
Chargepoint	22.2%	0.0%	0.0%	5.7%
Kitu		0.0%		0.0%
eMotorWerks	42.9%	0.0%	0.0%	18.8%
Total	31.3%	0.0%	0.0%	9.6%

% of Customers Passing (Daily kWh Intervals, with +/- 5% Threshold)				
	PG&E	SCE	SDG&E	Total
Chargepoint	44.4%	0.0%	0.0%	11.4%
Kitu		100.0%		100.0%
eMotorWerks	57.1%	14.3%	0.0%	31.3%
Total	50.0%	8.7%	0.0%	19.2%

### 4.3.2 Third-party Lab Testing Results

The utilities and CPUC Energy Division staff decided to conduct third-party laboratory testing due to the submeter inaccuracies observed in the field. Laboratory testing allowed for further isolation of the accuracy issues by eliminating factors such as variation in the location of the data loggers on the circuit and potential customer Wi-Fi issues. Test results from the independent laboratory<sup>63</sup> indicate that all three submeters integrated into the three manufacturers charging stations were not in compliance with the  $\pm 1\%$  accuracy standard for bench testing. A redacted<sup>64</sup> copy of the report provided by the lab is contained in Appendix G.

The best performing submeter was compliant with the accuracy standard in 14 of the 42 tests conducted on each charging station. Meaning, the best performing submeter was only compliant on one-third of the tests, and the compliance rate was even lower for the other two submeters. Tests were conducted at two (2) load levels, full load and 1% of full load, and two (2) PF levels, 1 and 0.5, with the exception of the ChargePoint unit which would not operate at PF levels below 0.81 at full load. Multiple voltage levels were also used for the range of tests with both high and low load levels and PFs to simulate the widest range of conditions the chargers might operate at in the field. While an insufficient numbers of tests at each load, PF, and voltage were

<sup>63</sup> The independent lab testing was conducted by MET Labs, based out of Baltimore Maryland. Results were provided in a report titled "TEL99908-PGE ALL TESTS USC Rev 1" delivered to Nexant on November 1, 2018.

<sup>64</sup> The details of the specific test results are confidential. Non-redacted versions were provided to the utilities and CPUC for review. The MDMA's each received a copy of the report where their specific tests were not redacted so they could review their own results.

conducted to determine the statistical significance of each of the three manipulated variables on the test results, some patterns were observed.

Combining and sorting all the individual test results by percent of registration versus the lab's reference standard suggests that the submeters for all three charging stations had the greatest percentage of error under light load test conditions equal to 1% of full load. Roughly 10% (12 of 126) of all tests resulted in registration errors that were at least 7% lower than actual energy supplied to the submeters (all were 1% load), with another 14% (18 of 126) of the test results showing 7% or higher registered energy use than was delivered. Registration errors greater than 7% (positive or negative) were observed at light load for both short and longer duration tests, and at all voltage levels. The most common factor among those tests appears to be the light load condition (21 of 30). All but two of the 21 light load tests with registration errors that exceeded 7% (positive or negative) were conducted at a PF<sup>65</sup> of one.

Approximately 43% (54 of 126) of all the tests results showed that the submeters would result in undercharging customers for energy deliveries by at least 1%, with 23% (29 of 126) of the tests meeting the  $\pm 1\%$  accuracy standard; the remaining 34% (43 of 126) of the test results showed registration errors greater than 1% that would overcharge customers for the energy delivered to the charging station.

Results from the test program are listed below in Table 4-4 . Note that the ChargePoint charging station could not be tested by the lab at a 0.5 PF for full load condition, as the relay would open creating a fault at 21A. A full load on the ChargePoint charging station is 32A. The lab determined that the minimum PF value for which full load testing could be conducted was 0.81; however, the lab was able to test at light load conditions at 0.5 PF.

**Table 4-4: Independent Lab Bench Test Results**

Charging Station	% of Tests in Compliance
ChargePoint CPH25	33.3% (14 of 42)
AeroVironment EVSE-RS	4.8% (2 of 42)
JuiceBox Pro 40	31.0% (13 of 42)

### 4.3.3 Source of Inaccuracies

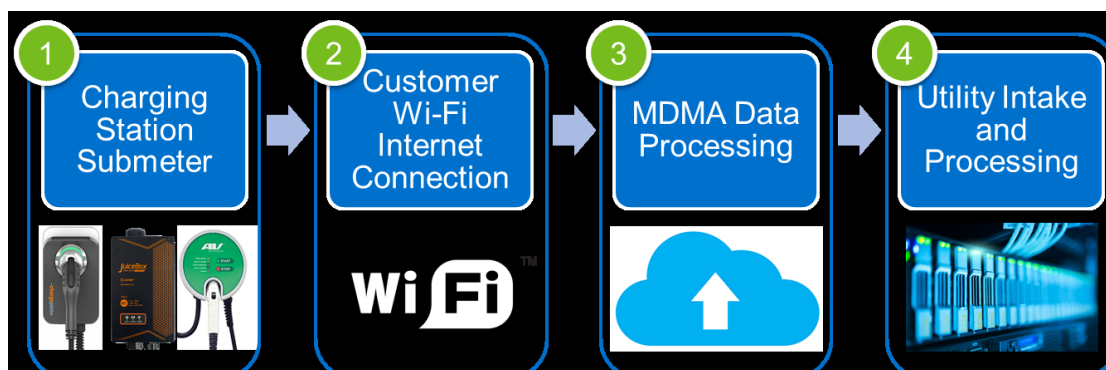
Figure 4-10 provides a high-level overview of the data flows between the submeter and the utility in order to provide visibility into potential sources of the inaccuracies. The potential sources for inaccuracies are organized by each step in the diagram. The decision to laboratory test the submeters was not part of the original test plan for the pilot. It came about when Nexant discovered that the submeters were not meeting the field performance standard (i.e.,  $\pm 2\%$  error) and PG&E brought it to our attention that the submeters were not meeting the minimum standard for performance in their in house laboratory tests.

The tests from the third-party laboratory were carried out to independently verify the results of the laboratory testing that had been carried out by PG&E and to help isolate the sources for inaccuracies. The field testing relied on data that passed through all four steps in the diagram. Although laboratory testing also relied on Wi-Fi, in the lab environment a high quality connection

<sup>65</sup> A PF of one indicates normal operating conditions on a circuit.

was established to remove this source of failure. Consequently, the laboratory testing was able to identify issues that were contained to steps 1 and 3 of the submeter systems.

**Figure 4-10: Data Flow Diagram**



#### 4.3.3.1 Charging Station Submeter

As discussed previously, the laboratory testing confirmed there are still issues with accuracy, even when the complications of customer Wi-Fi and utility data intake are removed. However, the lab testing still relied on retrieving charging data from the MDMA's online portal. This, in turn, required the data to be transmitted to the MDMA's cloud-based system and presumably processed in some way before being transmitted to the online portal.

Without a direct diagnostic output from the charging station, it is impossible to determine with complete certainty if the accuracy issues are from the submeter, data processing and storage, or both. Inclusion of a diagnostics tool in future submeter models, such as a light that blinks after every 1 kWh of electricity consumed can help isolate accuracy issues.

#### 4.3.3.2 Customer Wi-Fi Internet Connection

The potential intermittency of customer Wi-Fi was another possible source of data issues. This is because charging stations may only store a day of data and customer Wi-Fi, in certain circumstances, can become disconnected for a longer period. If this occurs, the submeter is not able to send charging data to the MDMA. A lack of charging data can lead to inaccurate customer bills or a loss of savings to the customer if only part of a billing cycle is recorded.

For example, the AeroVironment charging station has 24 hours of on-charging station data storage, whereas the JuiceBox Pro 40 can store up to 90 days of interval data. Based on these on-charging station storage capacities, if the Wi-Fi connection was down for more than 24 hours there is a potential for data loss with the AeroVironment model.

Based on the Nexant accuracy analysis in Section 4.3.1, there were instances where the data loggers indicated charging was taking place, but there was not any registered consumption from the submeters. We provide examples of this situation in Figure 4-5 where data points show consumption on the data loggers, but zero consumption from the submeters. These instances may be indicative of issues that interrupt communication between the charging station and the cloud based server.

#### 4.3.3.3 MDMA Data Processing

Another potential failure point is the MDMA's data processing, storage, and transmission systems. When Nexant inquired about the MDMA's internal data flows and handling practices,

the MDMAs responded that their internal processes are proprietary. Without insights to the specific data related processes, it is impossible to determine if any of the accuracy issues are a result of data processing errors. During Phase 2, ChargePoint and the utilities encountered data handling and process related challenges which required correcting the labeling of data intervals from end time to start time. This issue was resolved and resulted in improved data quality.

#### 4.3.3.4 Utility Intake and Processing

Once the data was received by the utilities, it was processed by varying levels of automation. PG&E provided Nexant with the original raw data files it received from the MDMAs and the data files merged with PG&E's whole premise consumption data to assist Nexant in isolating the accuracy issues. Nexant compared the data sets and confirmed that PG&E's data handling processes preserved the integrity of the data provided by the MDMAs. Nexant requested the original MDMA data from the other utilities, but it is our understanding the original raw data was not retained after processing. SCE noted they worked directly with ChargePoint and confirmed there were no differences between ChargePoint's raw data and the SCE data reformatted for billing purposes.

#### 4.3.4 Accuracy Testing Feedback from MDMAs

The MDMAs were provided a draft copy of this pilot evaluation report for review. Nexant responded to clarifying questions from ChargePoint via email. eMotorWerks raised several issues regarding the laboratory testing setup, laboratory testing specifications, and the field testing setup with data loggers. Nexant responded to eMotorWerks via a memorandum which is included as Appendix H. A high level summary of the issues raised and Nexant's response follows. Reviewers are encouraged to read the entire memorandum for greater detail.

Summary of eMotorWerks concerns and Nexant's response:

- **Concern 1: Invalid testing setup, inconsistent with NIST Handbook (HB) 44 protocols.**
  - Specifically, the point of measurement on the circuit was at the submeter and not at the output coupler at the end of the output cable as specified in HB44. eMotorWerks indicated there was potential for line losses contributing to the observed measurement error. eMotorWerks also noted there was equipment noted on the testing schematic in the laboratory report that could be a potential source for additional line loss.
  - Nexant consulted with MET Labs about eMotorWerks concerns. The technician indicated a simplified test circuit was pictured in the original report and provided an updated report with a new schematic to clarify. Equipment in question from the original diagram was not actually included in the testing circuit.
  - The updated report also included an inventory of the cable length and gauge that was used in the testing so that line loss could be calculated. Based on electrical engineering calculations, it was determined that if the metering point had been at the output coupler at the end of the output cable (a 25' length of 6 gauge cable at 240V at 32A) the expected line loss was 0.137%. Between the two eMotorWerks provided submeters, the errors were both positive and negative, indicating both over and under measurement. Since it is not possible for line loss to have

contributed to instances of over measurement, line loss cannot explain all the errors.

- In cases with under measurement, there were instances close to the  $\pm 1\%$  acceptance testing threshold that could be influenced by the potential of line loss. However, there were still many tests where the outcomes did not change. In summary, it appears the metering point can affect test outcomes, but not enough to change the overall conclusion that the submeters generally do not meet the  $\pm 1\%$  laboratory bench testing standard.

▪ **Concern 2: Laboratory Testing Specifications and Results Interpretation.**

- eMotorWerks primary concern was the weighting of the individual tests were biased towards tests of “edge cases” such as low PF or load levels that are not as common as full load testing.
- The utilities jointly developed the high level test specifications with Nexant. PG&E internal metering specialists further developed the specifics, and the final tests were then reviewed by the utilities and Nexant. It is Nexant’s understanding that the test scenarios were based of the ANSI C12 metering standard. Nexant offered to include a non-redacted set of test results in the appendix and refer the reader to the specific testing outcomes such that they can have the full data to draw their own conclusions. eMotorWerks did not respond to this offer, and the results remain redacted.

▪ **Concern 3: Field Testing Setup with Data Loggers.**

- eMotorWerks claims the field testing using data loggers is invalid due to the metering point not being at the output coupler at the end of the output cable.
- Nexant recognized the metering point (for the data loggers used in the study) as a confounding factor in this analysis, and took account of this factor by analyzing the accuracy of the meters at varying accuracy thresholds (i.e.,  $\pm 2\%$  and  $\pm 5\%$ ) over varying time intervals (i.e., 15 minutes and 24 hours). Line losses over a 100’ length of 6 gauge wire at 240V and 40A would produce line losses of approximately 1.3%. Therefore, the likely maximum line losses between the logger installed at the panel and the submeter is less than 1.3%, which is well inside of the  $\pm 5\%$  tolerance. Furthermore, while the accuracy of the submeter itself was likely a factor in the accuracy issues observed in the field testing, our results show that lost data through the backhaul system, or potentially from customer Wi-Fi issues is likely a larger factor affecting the performance of the submetering system. There were many instances where the data loggers in the study registered charging, but the submeters did not. These situations produce orders of magnitude higher errors than the small errors arising from calibration of the submeters.

#### 4.3.5 Accuracy Testing Summary

Based on both the field testing and the additional laboratory testing, the submeters included in this pilot did not meet the accuracy standard of  $\pm 1\%$  for acceptance testing in the laboratory or  $\pm 2\%$  in the field. Laboratory testing has identified accuracy issues in the submetering system, which includes the submeter and the cloud data processing. Without the addition of a diagnostic

tool integrated into the submeter, it is not possible to further determine the source of the inaccuracies. Intermittency of customer Wi-Fi appears to be the driver for data intervals where field loggers recorded charging and the submeters did not. The errors resulting from missing submeter data are significantly larger than the errors identified in the laboratory setting that were isolated to the submeter systems. Finally, the back and forth over the testing specifications and interpretation of results in the rounds of review and correspondence is a clear illustration of the importance of developing a standard for verifying submeter accuracy.

## 4.4 Customer Experience during the Pilot

A key objective for Phase 2 was to assess the experience of participating customers.<sup>66</sup> To that end, all Phase 2 pilot participants were contacted immediately after enrolling in the pilot with a request to complete a participant survey (the Welcome Survey) in June 2017. Participants then received an additional survey request in May 2018 at the end of the pilot (the Post Pilot Survey).

In addition, in order to better understand why customers may have reacted negatively to the submetering pilot experience, a separate survey was sent to customers who either withdrew from the pilot while it was underway or did not complete the enrollment process. The remainder of this section presents the survey results associated with the research topics described previously.

### 4.4.1 Welcome Survey

#### 4.4.1.1 PEV Ownership and Usage

A total of 372 participants (86% response rate) responded to the Phase 2 Welcome Survey. The survey showed that most of the Phase 2 participants owned a single PEV that was purchased or leased in 2016 or 2017. About 87% of respondents reported owning one PEV, 12% reported owning two PEVs, and 1% reported owning three or more PEVs. About 80% of respondents acquired their PEV(s) between 2015 and 2017, while about 20% of respondents' PEVs were purchased in 2013 or 2014.

The majority (61%) of survey respondents reported owning PEVs manufactured by Chevrolet, Nissan, BMW, Tesla, and Toyota. Table 4-5 presents frequencies of vehicle make and model as reported by survey respondents and includes 12 manufacturers in addition to the 5 listed above.<sup>67</sup>

**Table 4-5: Frequencies of PEV Make Owned by Pilot Participants**

PEV Manufacturer	Count
Audi	2
BMW	38
Chevrolet	115
Chrysler	1
Fiat	33

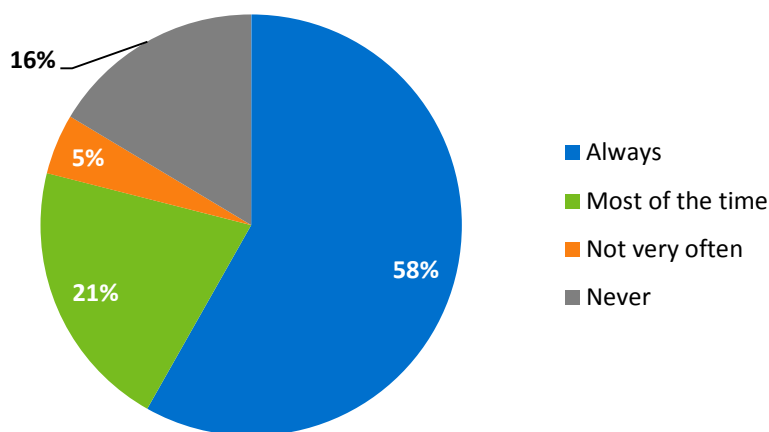
<sup>66</sup> See page 18 of the CPUC Decision 13-11.002 for a list of the goals of the California PEV Submetering Pilot.

<sup>67</sup> This table does not sum to (N=372) because participants who owned multiple PEVs were able to select more than one manufacturer.

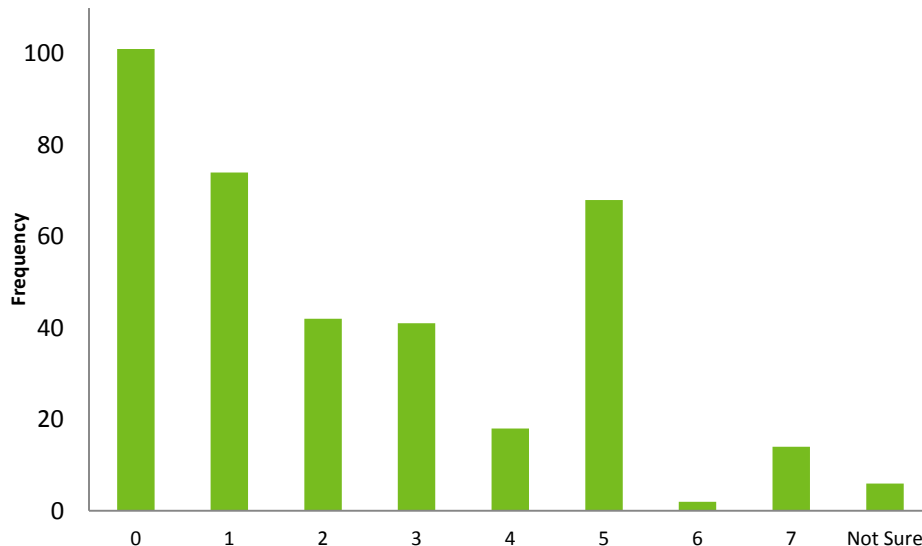
PEV Manufacturer	Count
Ford	25
Honda	2
Hyundai	2
Kia	7
Mercedes	11
Mitsubishi	2
Nissan	73
Prius	1
Smart Car	2
Tesla	14
Toyota	28
Volkswagen	33

At the time of the Welcome Survey, the majority of survey respondents (58%) reported that they always used a timer when they charged their PEVs, while 16% of respondents reported they never used a timer to control their PEV charging. The rest of the survey respondents reported that they used the charging timer most of the time or not often. Figure 4-11 shows the distribution of responses to the question of how often Phase 2 pilot participants use timers to control when their PEV charges.

**Figure 4-11: PEV Owners Who Use a Timer to Control Charging**

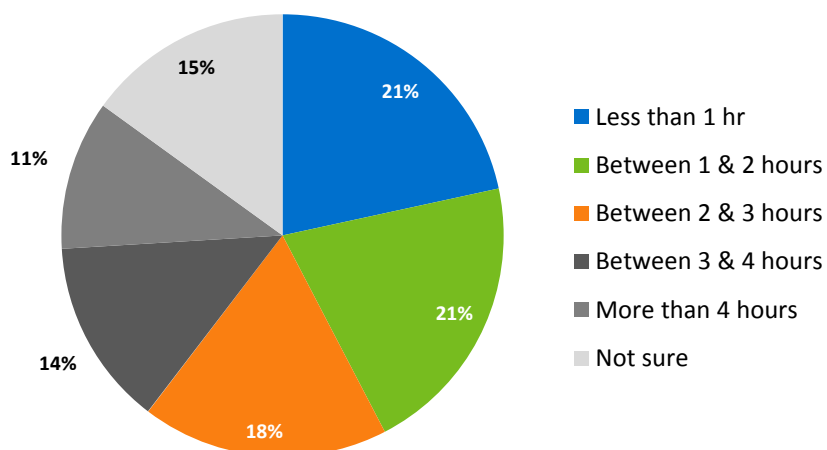


The Welcome Survey also included questions about how often and for how long pilot participants charged their vehicles away from home. Twenty-eight percent of respondents reported that they never charged their PEV away from home. Of those who reported charging away from home, 31% did so two or fewer days a week. Figure 4-12 shows the response frequencies for reported number of days of PEV charging away from the home.

**Figure 4-12: Number of Days per Week Charging Away from Home**

When charging away from home, a majority of respondents (68%) reported using Level 2 charging stations with 15% using DC fast charging stations. The remaining 17% of respondents stated that they are not sure about what type of charging station they use away from home.

Figure 4-13 shows the frequency of responses for each response category for average duration of away-from-home charging sessions. Charging sessions away from home were nearly equally divided between the choices of less than one hour, between one and two hours, and between two and three hours. This result shows that there is no “typical” duration of charging sessions away from the home for the PEV owners who participated in Phase 2.

**Figure 4-13: Average Duration of Charging Away from Home**

Approximately 45% of Welcome Survey respondents reported changing their charging to off-peak times after they enrolled in the pilot, while 40% said they had always charged off-peak, and 15% said they continued to charge on-peak.

#### 4.4.1.2 Customer Knowledge of Submetering Process and Electric Rates

A critical component of future submetering programs will be success in creating awareness of the program among potential participants, and providing useful information about how the program works compared with whole-house TOU. Responses to the Welcome Survey indicate Phase 2 participants were well informed about the rate options available to them. Over 90% of Welcome Survey respondents correctly stated that electricity used by their PEV is more expensive when charged during the peak period and less expensive during the off-peak period. A relatively large percentage (78%) of respondents also said that they were aware at the time of enrollment in the pilot that whole-house TOU electricity rates were also available to them. All customers correctly identified their whole-house rate. It is noteworthy that participants in Phase 2 of the pilot are all early adopters of both PEV technology and time varying rates. It is unlikely that the general population of PEV owners is as well informed about their electricity pricing options as the Phase 2 pilot participants.

#### 4.4.1.3 Customer Satisfaction

One of the most important metrics for the Phase 2 evaluation is the satisfaction of participants with the various aspects of the submetering service they received. To understand reported levels of satisfaction it is important to first understand customer expectations and motivations for participating in the pilot. The Welcome Survey results indicate that the two most important motivators for enrolling in Phase 2 of the pilot were:

- Ability to pay a lower rate for electricity used by the PEV.
- The availability of an incentive for the PEV charging station with submeter.

About nine out of 10 customers (86%) rated the ability to pay a lower rate for electricity used by their PEVs as an extremely important motivation for participating in the pilot; while about 71% of customers said the availability of an incentive for purchasing the PEV charging station was an extremely important reason. Other motivators that were frequently cited as extremely important were the cost of the vehicle charging station including the incentive and the ability to charge their vehicles more quickly. These were both rated as extremely important by about 59% of respondents. Other potential benefits from the technologies tested in the submetering pilot were identified as extremely important by less than a majority of respondents. Table 4-6 summarizes the motivations for Phase 2 participation.

**Table 4-6: Importance of Factors in Deciding to Enroll in the Pilot**

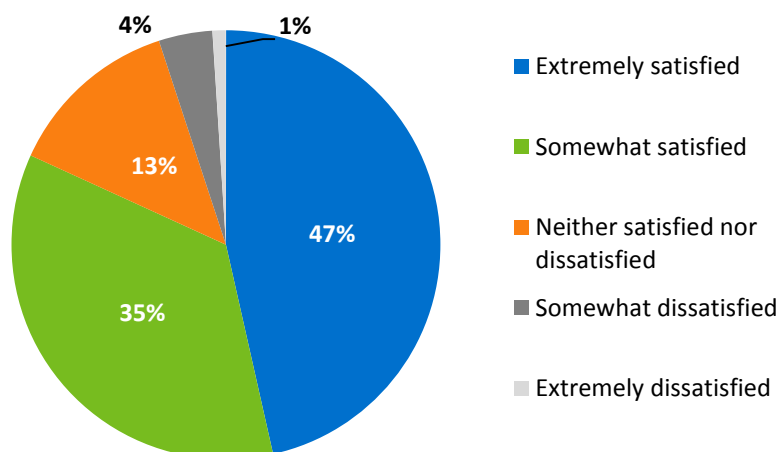
How important was each of the following aspects of submetering in deciding to sign up for the pilot?	Not at all Important	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Ability to pay a lower rate for electricity used by my PEV	1%	1%	11%	86%	97%
The availability of an incentive for the PEV submeter	2%	4%	23%	71%	94%
The cost of the vehicle charging station (including incentives)	4%	5%	31%	59%	90%
Ability to charge my vehicle more quickly	6%	8%	27%	59%	86%

How important was each of the following aspects of submetering in deciding to sign up for the pilot?	Not at all Important	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Ability to measure the amount of electricity my vehicle is using	5%	10%	43%	42%	85%
The safety and reliability of the charging station	7%	13%	33%	47%	80%
The ability to control the charging station from my smartphone	7%	14%	45%	34%	79%
Other aspect	31%	3%	10%	56%	66%

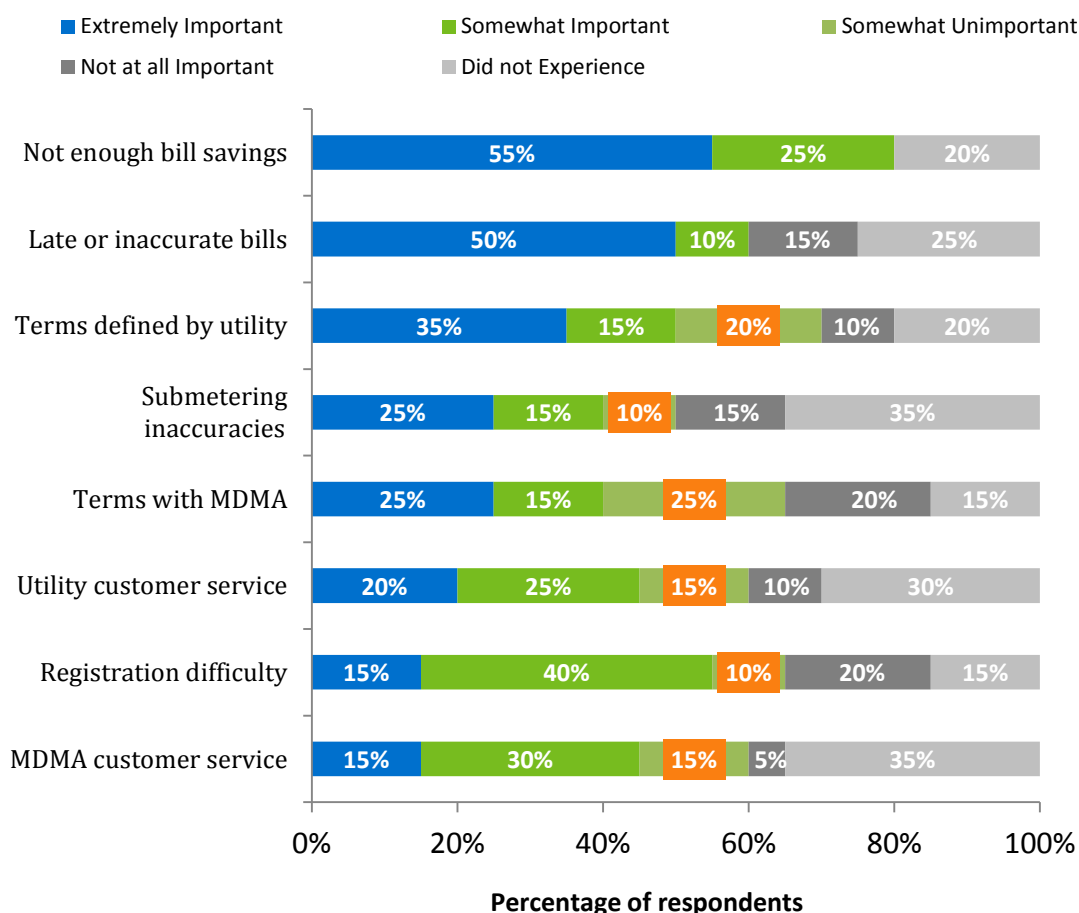
PEV submetering service affords the customer an opportunity to access their usage data either through a smartphone app or on the MDMA's websites. The available information includes estimates of the cost of electricity used by the vehicle and greenhouse gas emissions resulting from vehicle usage. It is notable that although this information was available to all the users in the pilot at the time of the Welcome Survey only about 57% of respondents stated that they had accessed the data collected by their submeters. Of the respondents who reported viewing their PEV electricity usage data, most (71%) reported inspecting the data pertaining to the cost of charging. Only 14% of respondents reported viewing the emissions data pertaining to their PEV electricity usage. Most of the respondents who reported viewing their usage data indicated they had viewed it through their smartphone app (88%) or through the MDMA's website (15%). About 15% of customers reported using their charger's onboard display to view the data.

Program participants were asked several questions about their satisfaction with the service delivered in the pilot near the end of the Welcome Survey. Keep in mind the fact that this survey was administered immediately after the customer began participating in the pilot and their experience up to that point may have been heavily influenced by the enrollment and installation process. Participants were first asked to rate their overall satisfaction with their submetering service using a 5-point scale ranging from: "Extremely satisfied," "to" "Extremely dissatisfied."

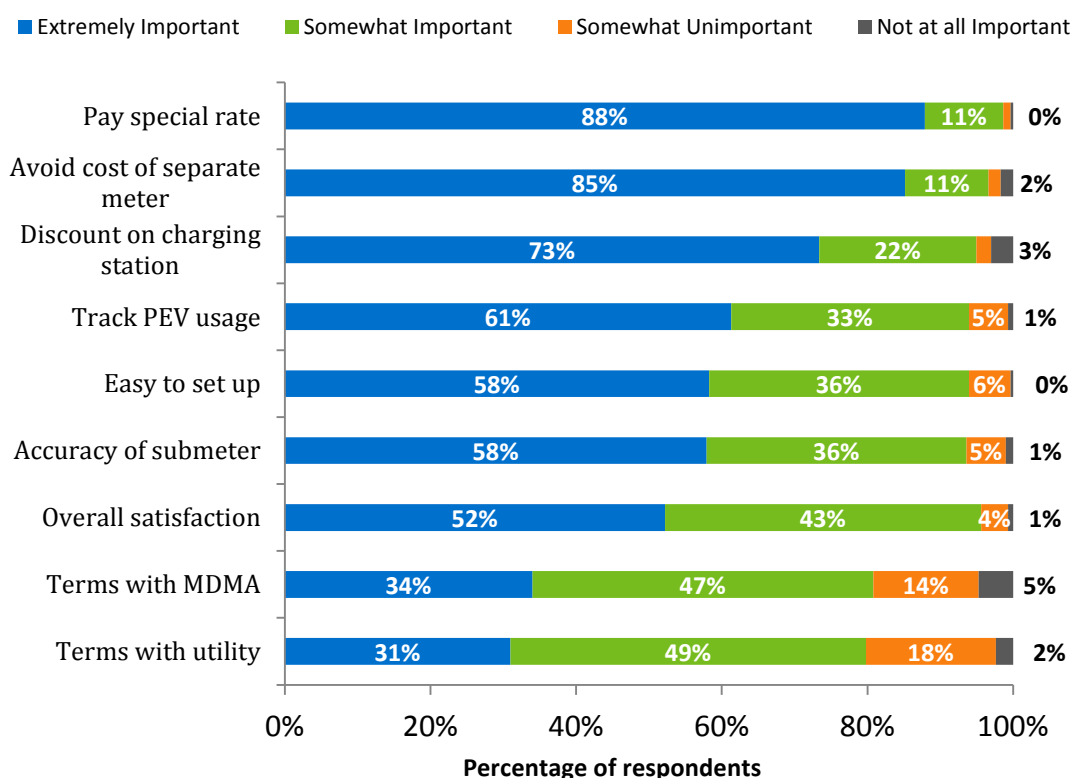
Figure 4-14 illustrates the distribution of responses to the overall satisfaction survey question. Most customers (82%) said that they were "extremely satisfied" or "somewhat satisfied," with submetering service; while 5% of respondents rated their level of satisfaction as "somewhat dissatisfied" or "extremely dissatisfied." The remaining 13% responded as "neither satisfied nor dissatisfied."

**Figure 4-14: Overall Customer Satisfaction with Submetering Service – Welcome Survey**

The majority of the 5% of the customers who reported they were dissatisfied with the submetering service, (55%, and 50%) indicated “not enough bill savings” and “late or inaccurate bills” were extremely important reasons for their dissatisfaction. Notably, only 15% of respondents rated “Registration difficulty” as extremely important reasons for dissatisfaction, but 40% rated it somewhat important, leaving registration difficulty to be the third most important reason for dissatisfaction. A breakdown of the reasons for dissatisfaction is presented in Figure 4-15.

**Figure 4-15: Reasons for Dissatisfaction with the Phase 2 Pilot – Welcome Survey**

As explained above, the vast majority of the respondents to the Welcome Survey indicated they were satisfied with their service. Not surprisingly, the respondents' rating on the importance of the various aspects of the service for determining their satisfaction with the service in the pilot corresponds with their reported motivations for participating in the pilot (see Table 4-6). In other words, the service in the pilot generally met their expectations. A breakdown of the reasons for satisfaction is presented in Figure 4-16.

**Figure 4-16: Reasons for Satisfaction**

In addition to overall satisfaction with the pilot, the survey also asked about satisfaction with specific aspects of the participant experience. Table 4-7 presents customer ratings of various aspects of the submetering service. The percentage shares for each rating and the top two box scores in the table only reflect those customers who experienced the designated service.

The aspects of the pilot that respondents reported the least experience with were the installation appointment, scheduling the installation, and utility customer service. The majority (55%, and 59%) of respondents reported not having experience with the scheduling of their installation, and the installation appointment itself. Additionally, 41% of respondents reported not having experience with utility customer service.<sup>68</sup>

Among respondents who reported experiencing the aspects of the pilot shown in Table 4-7, the highest rated aspects in terms of customer satisfaction were the safety and reliability of the charging station. Over 90% of respondents rated the safety and reliability of the charging station as very good or excellent. The third highest rated aspect of Phase 2 was the ability to access remote charging information, followed by scheduling of installations, remote charger control, and installation appointments for those who had experience with them.

The aspects of the pilot with the lowest satisfaction ratings as measured by the top two box scores were related to utility customer service, rate signup with the utility, and bill accuracy. About two thirds (64%) of respondents reported having a very good or excellent experience with

<sup>68</sup> The fraction of respondents who report having no experience with scheduling the installation, installation appointment, or utility customer service seems high. The most likely explanation for this result is that a member of the household other than the respondent was responsible for scheduling the installation of the charging station and interactions with the utility.

PEV rate signup with their utility and then 56% reported having very good or excellent customer service. Lastly, about 65% of respondents reported that PEV bill accuracy was very good or excellent.

**Table 4-7: Satisfaction Ratings for Specific Aspects of Phase 2 Pilot**

		Did Not Experience	Fair	Good	Very Good	Excellent	Top 2 Box
Safety of Charger		8%	0%	6%	30%	64%	94%
Charger Reliability		2%	3%	5%	23%	69%	92%
Access Remote Charging Information		9%	2%	9%	24%	65%	89%
Scheduling Installation		55%	3%	10%	32%	55%	87%
Remote Charger Control		10%	4%	9%	24%	63%	87%
Installation Appointment		59%	3%	12%	29%	56%	85%
Measurement Accuracy		21%	7%	13%	30%	50%	80%
Bill Savings		20%	9%	14%	24%	52%	76%
MDMA Customer Service		27%	9%	16%	33%	41%	74%
PEV Bill Accuracy		30%	14%	21%	31%	34%	65%
PEV Rate Signup with Utility	All Utilities	3%	14%	21%	30%	34%	64%
	PG&E	4%	17%	18%	32%	33%	65%
	SCE	2%	10%	28%	23%	38%	61%
	SDG&E	0%	16%	16%	42%	27%	69%
Utility Customer Service	All Utilities	41%	19%	25%	25%	31%	56%
	PG&E	40%	19%	24%	27%	30%	57%
	SCE	43%	19%	27%	21%	33%	54%
	SDG&E	40%	19%	22%	26%	33%	59%

A total of 48, or 13% of Phase 2 participants, also participated in Phase 1 of the PEV pilot. Of these 48 participants, 55% reported that their experience with Phase 2 of the pilot was better than their experience in Phase 1, 35% reported no change, and 10% reported their experience was worse.

In summary there are seven key takeaways from the results of the Welcome Survey:

1. Customers chose to participate in the pilot primarily because they believed they could pay a lower rate for electricity used to charge their electric vehicles at night; and because of the financial incentives that were available through participation.
2. The majority of customers in the pilot used the capabilities of the charging stations to schedule charging and viewed their usage through smartphone apps and MDMA websites, although these services were not critical to the consumers' choices to participate in the pilot.
3. Customers who participated in the pilot were well aware of the pricing schedule implicit in the rates they were paying for charging their PEVs.
4. The vast majority of customers participating in the Phase 2 pilot reported they were satisfied with the services they received during the pilot.

5. The small fraction of customers who reported they were dissatisfied with service during the early pilot were for the most part disappointed in the cost savings obtainable from the PEV submetering rate; or were frustrated by persistent billing problems.
6. Participants rated the safety and reliability of the charging stations, functionality of the control and information access services and services related to installing and maintaining the charging stations very highly.
7. They were less satisfied with other aspects of the service – particularly with the process required to sign up for the pilot and with customer service provided by both the utilities and MDMA.

#### 4.4.1.4 Issue Resolution

When customers indicated they had experienced problems in the course of the pilot the Welcome Survey asked follow-up questions about how well issues were resolved. Most pilot participants (95%) reported that they had not experienced any technical problems or dissatisfaction with their submetering services. Of the 5% (16 respondents) who reported technical problems with submetering, most reported issues were related to Wi-Fi connectivity, failure of charging equipment, inaccurate measurement data, or unsuccessful transmittal of measurement data to the utility.

Table 4-8 presents satisfaction ratings for the resolution of these technical problems.<sup>69</sup> About a third (31%) of respondents who experienced technical problems stated that the problem was still unresolved as of the time of the Welcome Survey. Because of the large percentage of customers reporting that their problems were not resolved, the top two box satisfaction score for this aspect of the service was very low at 32%.

**Table 4-8: Satisfaction Ratings for Resolution of Technical Problems**

	The Problem(s) is/are Still Unresolved	Extremely Dissatisfied	Somewhat Dissatisfied	Neither Satisfied nor Dissatisfied	Somewhat Satisfied	Extremely Satisfied	Top 2 Box
How satisfied were you with the resolution of the technical problem(s)?	31%	0%	6%	31%	19%	13%	32%

Eighteen pilot participants (6%) indicated that they were dissatisfied because they had experienced billing problems. Most of these customers described their billing issue as an increase in the amount they were used to paying. Other billing related problems included an issue with net metering, or a conflict created by another demand response program<sup>70</sup>. Table 4-9 presents satisfaction ratings for the resolution of billing problems. Notably, 56% of respondents said that their billing problem was still unresolved as of the time of the Welcome Survey. Again

<sup>69</sup> This question was only answer by participants who reported having technical problems.

<sup>70</sup> Customers were required to discontinue participation in demand response programs as a condition of service for the Pilot. Apparently, this requirement produced some latent dissatisfaction with the program

because of the percentage of unresolved problems, the top two box satisfaction score for resolution of billing problems is very low at 17%.

**Table 4-9: Satisfaction Ratings for Resolution of Billing Problems**

Question	The Problem(s) is/are Still Unresolved	Extremely Dissatisfied	Somewhat Dissatisfied	Neither Satisfied nor Dissatisfied	Somewhat Satisfied	Extremely Satisfied	Top 2 Box
How satisfied were you with the resolution of the billing problem(s)?	56%	6%	6%	17%	17%	0%	17%

#### 4.4.2 Surveys of Customers Who Withdrew from the Pilot and Prospective Participants Who Did Not Complete Enrollment

##### 4.4.2.1 Key Findings

Forty-two participants withdrew from Phase 2 of the pilot after they had started the service but prior to its conclusion. Ten of those customers completed a survey designed to discover their reasons for leaving the pilot prematurely. Of those who withdrew, 6 said they were dissatisfied with the submetering service, while 3 said they were satisfied, and 1 was ambivalent. Their experience during the enrollment process was not an important reason for their withdrawal. Nine out of 10 participants who withdrew from the pilot were satisfied with both the utility and MDMA enrollment procedures. The distribution of responses for submetering and enrollment process satisfaction is presented in Table 4-10.

**Table 4-10: Unenrolled Participant Satisfaction**

Satisfaction Rating	Submetering Service	Utility Enrollment Process	MDMA Enrollment Process
Extremely satisfied	10%	10%	10%
Somewhat satisfied	20%	80%	80%
Neither satisfied nor dissatisfied	10%	10%	10%
Somewhat dissatisfied	30%	0%	0%
Extremely dissatisfied	30%	0%	0%

Of the 10 customers who completed the Phase 2 Withdrawal Survey, 8 indicated “not enough bill savings” was an important reason for their decision to withdraw. A breakdown of the reasons for withdrawal is presented in Table 4-11. It is important to bear in mind the fact that “The ability to pay a lower rate for electricity used by my PEV” was among the top three reasons why customers who withdrew from the pilot actually enrolled in the first place, per Table 4-11. Interestingly, a total of 9 out of the 10 participants who withdrew from the pilot indicated that they would participate in another pilot related to PEVs. Since most of the respondents who withdrew from the pilot reported experiencing higher electricity cost and billing errors, it is reasonable to conclude that another pilot that did not contain these problems would be of interest to them.

**Table 4-11: Importance of Factors in Deciding to Withdraw from the Pilot**

How important was each of the following aspects in contributing to your un-enrollment from the pilot?	Not Important at All	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Not enough bill savings	0%	10%	20%	60%	80%
Other billing problems	13%	0%	0%	50%	50%
Errors resulting from submeter accuracy	10%	0%	0%	40%	40%
Late or inaccurate bills	10%	10%	10%	30%	40%
Utility customer service	30%	0%	20%	20%	40%
MDMA customer service	20%	0%	20%	10%	30%
Other technical problems	14%	0%	0%	29%	29%
Other non-technical or billing problems	0%	0%	0%	17%	17%
No longer have an EV	10%	0%	0%	0%	0%

Sixty-three of the customers who originally expressed interest in participating in the pilot did not sign and return the CEA that is required to initiate the enrollment process. Another four customers signed and returned the CEA but did not complete the enrollment process after starting it. A breakdown of reasons provided for not completing the enrollment process is provided in Table 4-12.

The majority of respondents (72%) selected the open-ended response as the most important reason for not completing their enrollment. Table 4-13 summarizes the reasons provided by customers in answer to this important open ended question. Most of the reasons mentioned by customers had to do with charging station concerns. The most cited reason (5 customers) was that they did not want one of the qualifying charging stations. Another 3 customers expressed concern with the cost of the eligible charging stations; and 3 customers were concerned that they might buy a charging station only to discover that they were not otherwise qualified for the pilot.

Aside from the open-ended response, the most important reason for not completing enrollment in the pilot as indicated by its Top 2 Box score in Table 4-12 was “The enrollment process was complicated”. The third most important was “I did not think I would save enough with the rate offered,” which corresponds to the most popular reason for withdrawing from the pilot as discussed previously.

**Table 4-12: Reasons for Not Completing or Beginning the Enrollment Process**

How important was each of the following aspects in your not completing enrollment for the pilot?	Not Important at All	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Other (please explain)	28%	0%	0%	72%	72%
The enrollment process was complicated	21%	10%	48%	21%	69%
I didn't think I would save enough with the rate offered	27%	16%	30%	27%	57%
I would have wanted to stay on the rate for more than 12 months	45%	19%	22%	13%	36%
I didn't want to limit my charging on weekday afternoons / evenings	52%	18%	22%	7%	30%
I didn't think the rate was compatible with my net metered PV solar production	60%	13%	10%	16%	27%
I didn't want to or couldn't un-enroll from other programs (auto-pay, demand response, etc.)	54%	21%	7%	18%	25%
I didn't qualify for the pilot for another reason (please explain)	68%	13%	6%	13%	19%
I don't usually charge my car at home	73%	16%	6%	4%	10%

**Table 4-13: Stated Reasons for not Completing Enrollment**

Reason	Count
Did not want qualifying charging station	5
Risk of not qualifying	3
Cost of eligible charging station	3
Missed deadline	2
Already on TOU Rate	1
Couldn't use existing charging station	1
External cost factor	1
Net metering conflict	1

### 4.4.3 Post Pilot Survey

#### 4.4.3.1 PEV Ownership and Usage

The Post Pilot Survey showed that 77% of respondents reported owning one PEV, while 22% reported owning more than one PEV, and 1% reported having not owned a PEV at the time of surveying.

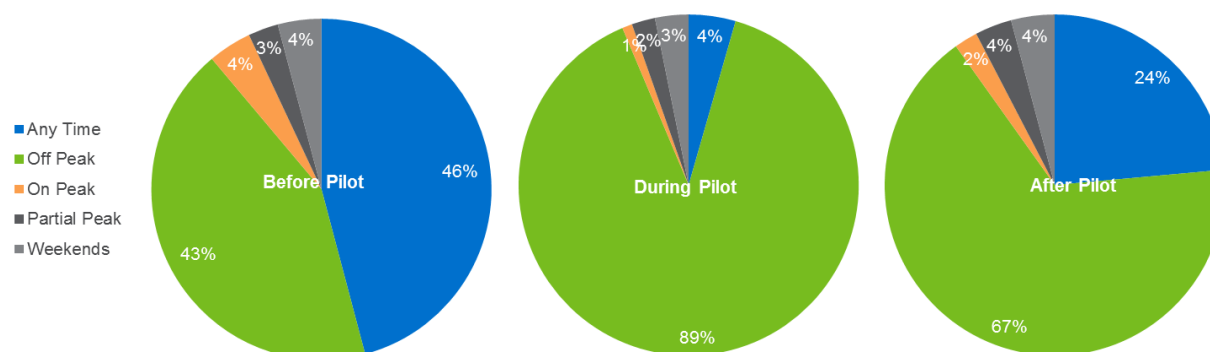
At the time of the Welcome Survey, 46% of participants indicated they would charge their PEV at any time, 43% indicated they would charge off-peak on weekdays, and 4% indicated they would charge on-peak time. Importantly, almost half, 46% of respondents to the Post Pilot Survey reported changing their behavior during the pilot.

The percentage of respondents to the Post Pilot Survey who reported charging any time fell from 46% to 4%; the proportion who reported charging off-peak on weekdays rose from 43% to 89%; and the percentage of participants who reported charging on-peak fell from 4% to 1%.

After their participation in the pilot was completed, the number of participants who reported charging at any time increased from 4% to 24%. Charging behavior is visualized in Figure 4-17. These responses provide startling evidence that offering the submetering service dramatically changed customer charging behavior.

However, as is the case with many behavioral interventions and particularly those involving pricing, the effect of the intervention diminishes after the program ends. There is still a substantial effect, but it is unknown how long these effects persist.

**Figure 4-17: Participant Reported Charging Behavior**



#### 4.4.3.2 Customer Knowledge of Submetering Process and Electric Rates

When two service providers offer a combined service, it is important for both service providers that customers correctly understand who have the responsibility for the various aspects of the service that is being delivered. This is necessary so that customers understand who they should be dealing with in correcting service problems, and so that the performance of one of the providers does not damage the reputation of the other. To understand how well customers understood the responsibilities of the service providers, the Post Pilot Survey asked participants who they thought was responsible for ensuring that important aspects of the submetering service were working properly.

Table 4-14 displays the percentages of survey respondents who said they believed the utilities or MDMAs were responsible for supplying various aspects of the service. It is clear in the table that customers do not draw sharp (or correct) lines in assigning responsibility for supplying the various aspects of the submetering service to the service providers.

For example, although responsibility for addressing technical problems with the submeters was solely the responsibility of the MDMAs, many customers did not think so. While the majority of customers (60%) reported that MDMA was responsible for addressing technical problems with the submeters, a substantial minority (40%) believed that this responsibility rested with the utilities (15%) or with both the utilities and the MDMA (25%). A similar pattern is present in the perceived distribution of responsibility for “ensuring measurements of the electricity used by your vehicle are accurate”, “measurement of the electricity used by your vehicle”, and “resolving errors in the measurement of electricity used by your vehicle”. The apparent confusion on the part of customers about the relationship between the utilities and MDMA and the distribution of responsibility for delivering the various aspects of the service is something that any future program design must directly address to improve customers satisfaction with services offered by the utilities and the MDMA.

**Table 4-14: Opinion of Responsibility – Post Pilot**

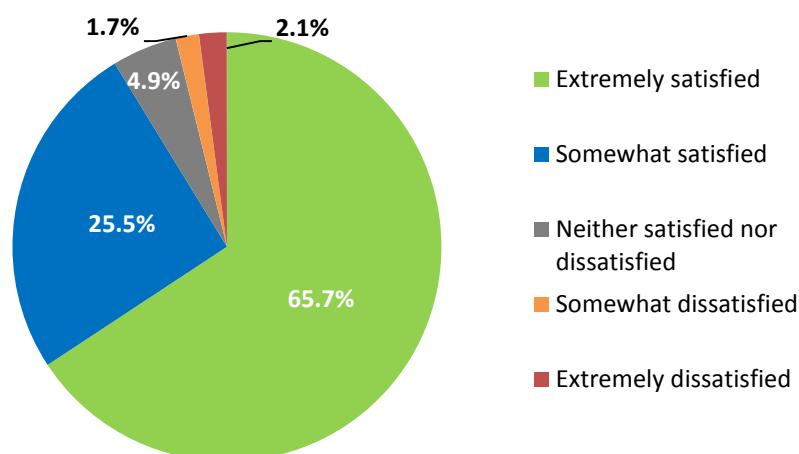
Aspect	Utility	MDMA	Both
Addressing technical problems with the submeter	15%	60%	25%
Ensuring measurements of the electricity used by your vehicle are accurate	10%	44%	47%
Ensuring your bills are accurate	57%	1%	42%
Ensuring your bills are timely	66%	1%	34%
Measurement of the electricity used by your vehicle	10%	41%	49%
Resolving errors in the measurement of electricity used by your EV	18%	28%	54%

In the Post Pilot Survey participants were asked to state whether they thought that an arrangement similar to the one in Phase 2 in which the MDMA installs and maintains the submeter and the utility is responsible for calculating the bill and receiving payment would be the best approach going forward assuming roughly the same pricing and program features. About two thirds (66%) of respondents said that the approach they experienced in the pilot would be best. Seventeen percent indicated that an arrangement in which their utility is responsible for all aspects of the service would be best, and another 17% were unsure. It is worth noting that among customers who were dissatisfied with the pilot experience, about one third stated they would prefer the utility to be responsible for all aspects of the service. This suggests that some customers, particularly those who had a bad experience, would like a choice to have a utility implemented solution.

#### 4.4.3.3 Customer Satisfaction

Similar to the Welcome Survey, the Post Pilot Survey also dealt with the topic of customer satisfaction in Phase 2. Participants were again asked to rate their overall satisfaction with their submetering service using a 5 point scale ranging from “Extremely satisfied” to “Extremely dissatisfied”. Figure 4-18 illustrates the distribution of responses to the overall satisfaction survey question.

At the end of Phase 2 of the pilot (i.e. after 12 months of service) approximately 91% of customers said that they were “extremely satisfied” or “somewhat satisfied”, 4% of respondents rated their level of satisfaction as “somewhat dissatisfied” or “extremely dissatisfied”, and 5% responded as “neither satisfied nor dissatisfied”.

**Figure 4-18: Overall Customer Satisfaction with Submetering Service – Post Pilot**

Fifty-one percent of the customers who said they were satisfied with the pilot reported that the ability to pay a lower rate and reduce their electric bill was the most important reason for their satisfaction. Thirty-four percent of the satisfied customers said that the fact that submetering was easy to set up was their most important reason for satisfaction. The distribution of rankings for satisfaction reasons is presented in Table 4-15.

**Table 4-15: Reasons for Satisfaction – Post Pilot**

Reason / Ranking	First	Second	Third	Fourth	Fifth
Ability to pay a lower rate and reduce your electricity bill	51%	33%	10%	6%	0%
Submetering was easy to set up	34%	31%	18%	15%	2%
Avoiding the cost of installing a second meter	10%	25%	31%	30%	3%
Ability to track your PEV usage separately from your household usage	3%	8%	38%	48%	3%
Other. Please explain:	3%	2%	3%	2%	91%

Of the 13 respondents who reported being dissatisfied at the end of the pilot, three stated that billing accuracy was the most important factor leading to their dissatisfaction; another three stated an increase in their electric cost to be the most important reason for dissatisfaction. Two customers reported issues with the general design of the TOU rates, and two more customers said their dissatisfaction was due to compatibility issues with their rooftop solar. Finally, one customer reported customer service from MDMA to be the primary reason for their dissatisfaction, another one reported it to be from utility customer service, and one customer reported it to be from bill lateness. The reasons for dissatisfaction in Phase 2 of the pilot are presented in Table 4-16.

In general, the NEM customers in the pilot were dissatisfied that their PEV charging would not be off-set by their solar generation. The utilities judged the incoming PEV charging data to be “failed intervals” if submetering loads during a given interval exceeded the whole-house loads measured at the smart meter. Failed intervals could be caused by customers with rooftop solar who charged their PEV during generation. When this occurred, their PEV charging kWh exceeded their net kWh (total household kWh including PEV charging – generation kWh) resulting in failed intervals. In these cases, the usage from the submeter was not netted out of the whole-house load and the customer paid the whole-house rate for charging their PEV, which was often lower than the on-peak price from the PEV rate.<sup>71</sup> If a customer charged on-peak and did not exceed the smart meter net kWh, they paid the high on-peak price from the PEV rate.<sup>72</sup> Interestingly, this situation could lead to a lower cost for PEV charging in some instances.

**Table 4-16: Reasons for Dissatisfaction with the Phase 2 – Post Pilot**

Dissatisfaction Responses	Frequency
Billing Accuracy	3
Cost	3
Rate Structure	2
Solar Issue	2
Customer service or support from MDMA	1
Customer service or support from utility	1
Lateness of bills	1
<b>Total</b>	<b>13</b>

Another important indication that Phase 2 customer satisfaction was high is the fact that 88% of participants indicated that they would recommend submetering service to a friend or colleague. When asked if they would participate in a program with roughly the same pricing and features, 94% indicated that they would, and 100% of respondents believed that such a program would be an important service for the utility to be offering to customers. When asked if they thought they saved money due to the pilot, 76% of the responders indicated they did, 9% thought they did not, and 15% were unsure.

#### 4.4.3.4 Issue Resolution

Customers who rated certain aspects of the submetering service as fair or poor on the Welcome Survey were asked whether they had noticed a change in this aspect of the service on the Post Pilot Survey. About half (14) of the respondents who rated bill accuracy as poor or fair on the Welcome Survey said that this aspect of their service had improved by the end of the pilot. This was also true for those who rated measurement accuracy of the electricity consumed by the vehicle as fair or poor.

<sup>71</sup> This outcome varied by utility and rate.

<sup>72</sup> This is currently a limitation of SCE's manual subtractive billing process that must be corrected if the CPUC authorizes the submetering protocol. It is unknown if this was also an issue at PG&E and SDG&E due to staff turnover.

The majority of respondents believed that their ability to control their charging station remotely improved, while the majority of respondents believed that the customer service provided by MDMA and utilities did not. A breakdown of responses is listed in Table 4-17.

**Table 4-17: Improvement Ratings for Specific Aspects of Phase 2 Pilot**

		Became Worse	Did Not Change	Improved
PEV bill accuracy		1	13	14
Measurement accuracy		-	6	8
Remote charger control		1	1	7
MDMA customer service		-	14	6
Access remote charging information		1	-	2
Utility Customer Service	All Utilities	4	19	9
	▪ PG&E	3	10	5
	▪ SCE	1	7	4
	▪ SDG&E	-	2	-

## 4.5 Data and Billing Issues and Resolution

To further assess the customer experience, the utilities tracked the customer inquiries that they received over the course of Phase 2 of the pilot. The utilities established internal systems to track data and billing issues, and Nexant tabulated and analyzed the data.

The tables for each utility are presented separately because each utility tracked and categorized data differently. Table 4-18 shows the customer inquiries received by SCE over the life of the pilot. The most common inquiries were for program enrollment status, general rate, and questions or complaints about late bills.

**Table 4-18: SCE Total Customer Inquiries**

<b>SCE Customer Inquiries</b>		
<b>Category</b>	<b>Count</b>	<b>Percent</b>
Enrollment status	31	45%
General rate info	10	14%
Delayed bill	6	9%
Bill accuracy	6	9%
Request to change rate	3	4%
Pilot Info	2	3%
Moving	2	3%
NEM info	2	3%
General info	2	3%
Eligibility	1	1%
View bill online	1	1%
Hardware	1	1%
Rebate	1	1%
Online data availability	1	1%
<b>TOTAL</b>	<b>69</b>	<b>100%</b>

Table 4-19 shows the customer inquiries received by PG&E. The most common inquiries were issues with MDMA data,<sup>73</sup> conflicting demand response program enrollment, and general inquiries to better understand the program.

<sup>73</sup> Customers would bring data issues to PG&E's attention when bills appeared to be incorrect.

**Table 4-19: PG&E Customer Inquiries**

PG&E Customer Inquiries	
Category	Percent
Issue with MDMA data (no or bad data)	38%
Customer enrolled in prohibited program (Rule 24, AP, BPP)	18%
Program clarity	10%
Customer satisfaction	8%
Communications	5%
Customer enrollment documentation incorrect or incomplete	5%
Customer issue	5%
PG&E process	5%
Technology issue	5%
<b>Total</b>	<b>99%</b>

Table 4-20 shows the customer inquiries SDG&E received. The most common inquiries were requests to opt-out of the program, rate inquiries, and general program inquiries. In total, SDG&E, which is the smallest of the three utilities, received the fewest number of inquiries (9) about the pilot.

**Table 4-20: SDG&E Rate Inquiries**

SDG&E Customer Inquiries		
Category (Nexant classification)	Count	Percent
Request to opt-out of pilot program	3	33%
Rate inquiry	2	22%
General program inquiry	2	22%
Customer enrolled in prohibited program (Rule 24, AP, BPP)	1	11%
Already enrolled in TOU rate	1	11%
<b>Total</b>	<b>9</b>	<b>100%</b>

Starting with Table 4-18, we can see that SCE customers most frequently called about “enrollment issues” while PG&E customers most frequently called about “issues with MDMA data”. SDG&E received far fewer inquiries in general but received the most inquiries about opting out of the program.

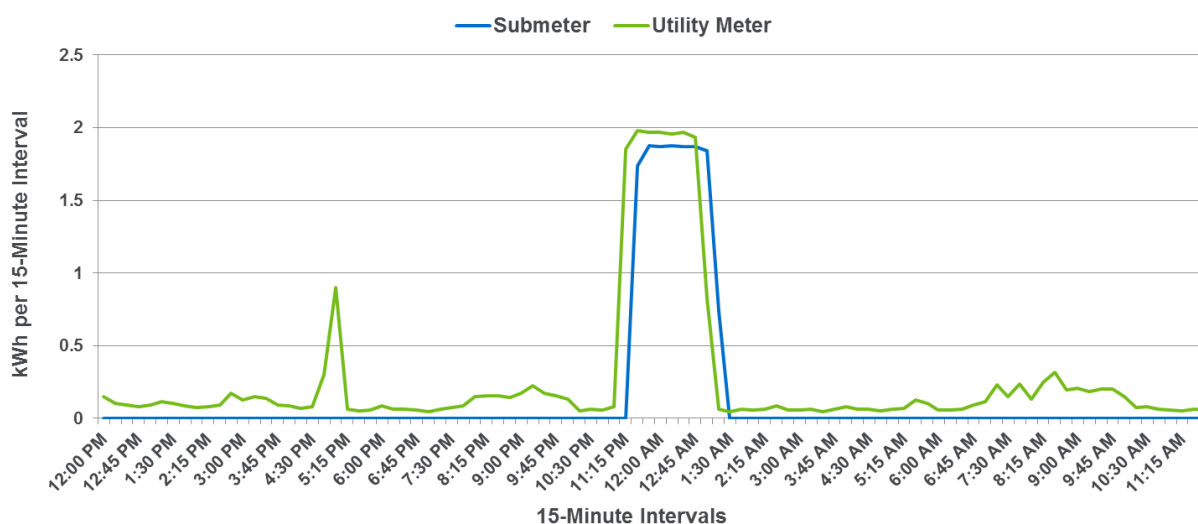
### 4.5.1 Submeter Time Synchronization Issues and Resolutions

The utilities and MDMA addressed several data issues early in Phase 2 of the pilot. One such issue was a MDMA mislabeling all submeter data as 15-minute interval beginning rather than 15-minute interval ending (this problem occurred in both phases of the pilot with different MDMA). As shown in Figure 4-19, this resulted in a 15-minute data shift. This error could result in charging consumption being billed at the wrong hourly TOU rate. It also resulted in instances where the submeter data exceeded the premise level meter data, which triggered errors in the billing systems. As a rule, utilities rejected any submeter measurements where this occurred and billed all usage for those intervals on the whole-house rate. Per the PEVSP tariff, any incorrect bills due to data errors of this kind were not updated retroactively in the event that the submeter data was corrected at a later time.

The utilities and MDMA resolved this issue through meetings on the telephone and a series of emails over several weeks.

The utilities also encountered issues with MDMA not always meeting the data delivery deadline. The utilities chose to contact MDMA to work through the data delivery issues. This caused delays in bills for the affected customers. This issue continued through all twelve months of the pilot.

**Figure 4-19: Example of Submeter Time Synchronization Issue**



## 4.6 Cost Estimation

In order to assess the cost effectiveness of submetering, decision-makers must understand the cost and potential savings of installing a submeter, as compared with installing a utility-grade meter, or enrolling on a whole-house TOU rate. Further, decision-makers must understand the overall cost to utilities of establishing a submetering protocol and implementing the utility billing system changes necessary to accommodate submetering at scale.

This section presents cost estimates for these scenarios. We base these estimates on information provided by the utilities and the MDMA, and from publicly available data. The utilities provided cost estimates that allow for general comparison of utility and third-party

submetering costs, but these estimates will require further refinement<sup>74</sup> before they can inform final estimates such as those typically included in a formal utility funding application.

Nexant requested cost data from the utilities via a standardized template<sup>75</sup> and from the MDMAs via email. The utilities deemed the cost data was proprietary;<sup>76</sup> therefore the range of costs and the average cost across the three utilities is presented in the tables in this section rather than identifying the cost details at the individual utility level.

The primary comparison in the cost section is between two service models. Service Model 1 is defined as a customer installing a separate utility-grade meter. Service Model 2 is defined as third-party submetering with subtractive billing consistent with Phase 2 of this pilot. Both service models allow for customers to pay a separate rate for charging their PEV that is different from the rate for the rest of the household energy usage.

Customer costs can vary significantly based on location and on the existing electrical wiring configuration at each customer's premise. For example, labor costs are significantly higher in the San Francisco Bay Area as compared to Southern California. The configuration and location of existing wiring relative to the desired charging location can also create significant cost differences as well.

The remainder of the cost estimation section is organized in four parts: Service Model 1: the cost of installing a separate utility-grade meter; Service Model 2: the cost of installing a submeter at full scale with automation; a cost comparison; and a summary. The first three subsections are further divided into customer and utility perspectives. The cost comparison section includes examination of installation costs, energy costs, and payback periods for customers under a variety of scenarios.

The utility perspective portion of the cost comparison section reports the costs incurred during the pilot, and provides a comparison with the expected costs per customer at scale achieved through automation. The summary section presents the key takeaways from the comparison section and documents how this pilot evaluation meets the CPUC Decision 13.11-002 requirements and sufficiently addresses the cost comparison questions.

#### **4.6.1 Service Model 1: Cost of Installing a Separate Utility-Grade Meter**

Installing a utility-grade meter to separately meter PEV charging creates several costs to both the customer and the utility. These include the customer's costs to install new equipment, and cost of the meter and related installation costs for the utility.

In both this service model and the submeter service model it is assumed the customer is starting with no existing PEV charging related infrastructure or charging station. There are two ways a customer could approach Service Model 1. A customer could simply charge their vehicle without a charging station.<sup>77</sup> We label this Scenario A. A customer could also elect to install a

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<sup>74</sup> Reasons for refinement are discussed in the specific cost sections.

<sup>75</sup> The template used for cost data collection is presented in Appendix F.

<sup>76</sup> The completed utility cost template workbooks were provided to the CPUC Energy Division staff for review.

<sup>77</sup> This scenario is presented because it is possible a customer may elect to continue charging at Level 1, or charge at Level 2 directly from a 240V outlet without a charging station. Tesla provides a NEMA 14-30 adapter that works with a normal 240V dryer plug. Source: <https://electrek.co/2016/08/25/tesla-charging-adapter-dryer-outlets-nema-14-30/>

charging station at their home; we label this Scenario B. Both scenarios require the installation of a new panel for the second meter. The purchase of a charging station is a customer preference related to the individual situation at each customer's charging location. Under some circumstances, a customer may want a charging station based on design, convenience, or safety needs.<sup>78</sup>

Figure 4-20 provides a diagram to illustrate the difference between the two scenarios. Both scenarios start with the electricity (A) being delivered to two separate panels and meters (B & C). One panel with the meter (C) delivers and measures electricity for the house (E). The additional panel with the meter (B) delivers and measures electricity for PEV charging (D).

The difference between the scenarios is the installation of a charging station (F) in Scenario B. Details regarding the two scenarios and the associated costs are covered in the customer perspective section.

**Figure 4-20: Illustration of Service Model 1, Scenario A and Scenario B**

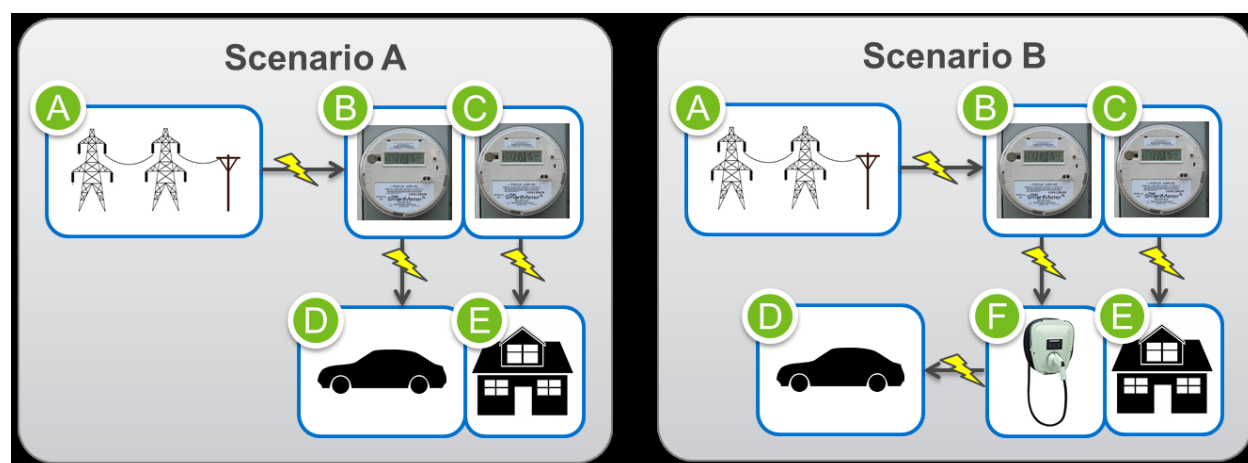


Table 4-21 presents a summary of the cost estimate data for installing a separate utility-grade meter.<sup>79</sup> The top portion of the table contains the costs to the customer, and the lower portion represents the utility costs. Under Scenario A, a customer can expect to pay approximately \$1,650 to have a separate utility-grade meter installed. If that customer also elected to purchase and install a charging station, costs would increase by approximate \$1,100 and result in a total cost of approximately \$2,700 to \$2,750. The average cost to a utility to install the second meter is approximately \$220. The total cost to a customer and utility is approximately \$1,900 under Scenario A with no charging station, and \$2,950 for Scenario B including the purchase and installation of a charging station.

Scenario B is provided for cost information purposes, but we assume most customers would choose Scenario A because it is the lower cost option. Most, if not all, PEVs come with a

<sup>78</sup> Availability and length of existing charging related cables and adapters may be a factor. Charging stations also generally have a receptacle or cap for securely storing the output end of the cable when not in use to avoid issues such as weather exposure. Charging cables supplied with the vehicle may not have a cap and supplied cables may be inconvenient for a customer to use regularly depending on if or how it is stored in the vehicle.

<sup>79</sup> The primary source for this data was the utility workbooks. Additional cost data references will be noted in the customer and utility perspective sub-sections.

charging cable; so a charging station is often not necessary. Accordingly, Scenario A will be used as the default assumption in subsequent cost comparisons in the remainder of this section.

**Table 4-21: Service Model 1-Traditional Separate Utility Revenue-Grade Meter Cost Estimate**

Paid By:	Cost Component	Average	Range
<b>Customer</b>	Service Panel Related Costs	\$1,640	\$1,600 to \$1,700
	Basic Non-networked Charging Station	\$467	\$179 to \$635
	Charging Station Installation	\$616	\$384 to \$866
	<b>Scenario A: Total Cost with no Charging Station</b>	<b>\$1,640</b>	<b>\$1,600 to \$1,700</b>
	<b>Scenario B: Total Cost with Charging Station</b>	<b>\$2,723</b>	<b>\$2,163 to \$3,201</b>
<b>Utility</b>	Utility Meter & Labor Cost	\$219	\$120 to \$388
	<b>Total Utility Cost</b>	<b>\$219</b>	<b>\$120 to \$388</b>
<b>Total Costs</b>	<b>Total Cost to Customer &amp; Utility: Scenario A</b>	<b>\$1,859</b>	<b>\$1,720 to \$2,088</b>
	<b>Total Cost to Customer &amp; Utility: Scenario B</b>	<b>\$2,943</b>	<b>\$2,283 to \$3,589</b>

#### 4.6.1.1 Customer Perspective

The primary costs to the customer include the service panel where the new meter is installed and the potential purchase and installation of a charging station. Under Scenario A, costs related to the service panel installation include materials, labor, permit, and city inspection. Materials will vary by installation, but include a new service panel and may also include: weatherhead and riser where the electrical service wires connect to the home above ground; and installation of a circuit from the second panel to the charging location.

According to the utilities, the average cost to the customer under Scenario A is approximately \$1,650. However, the cost could be lower than this estimate if the customer has existing wiring<sup>80</sup> or the cost could be significantly higher with complexities such as a detached garage significantly distant from the main panel which would require trenching. The utilities stated they are aware of installation costs as high as \$8,000 in extreme cases.

Scenario B includes all of the costs from Scenario A, but also includes the cost of purchasing and installing a charging station. In this example, we assume the customer is purchasing a basic model non-networked charging station. This means the charging station does not have Wi-Fi or other means of connecting to the internet to provide charging information or related features through a web based customer portal or smartphone app. Basic charging stations tend to cost about \$450,<sup>81</sup> which is about \$200 less than the network connected charging stations with submeters used in Phase 2 of the pilot.

<sup>80</sup> An example would be if there was an existing 240V circuit to the garage not being used.

<sup>81</sup> [https://www.amazon.com/s/ref=nb\\_sb\\_noss\\_1?url=search-alias%3Daps&field-keywords=ev+charging+station](https://www.amazon.com/s/ref=nb_sb_noss_1?url=search-alias%3Daps&field-keywords=ev+charging+station) visited November, 2018. ClipperCreek LCS-20 (\$379), ClipperCreek HCS-40 (\$565), Siemens US2 (\$429).

The average cost for a customer to install a charging station is approximate \$600 based on actual project cost data from 119 California customers provided on [homeadvisor.com](http://homeadvisor.com).<sup>82</sup> The expected cost of a basic charging station and installation is approximately \$1,100. A customer can expect to pay approximately \$2,700 when the charging station is added to the service panel related costs in the second scenario. Under both Scenario A and B the customer may pay a fee of up to \$2.76 per month for the meter.<sup>83</sup>

To install a separate utility-grade meter a customer must hire a licensed electrician and reach out to the utility to start the process. The electrician would come out to the premise and determine the work that needs to be completed. Key issues they must evaluate include how or whether to install the second panel in order to prepare it for a second meter, and how to install the wiring for the circuit to the location where the PEV will be charged. The utility may also send a representative to the site to determine whether the current electric service can support a PEV, or whether the service needs to be upgraded.

Prior to commencing the work, the electrician needs to obtain a permit from the city or local jurisdiction. Once the permits are obtained, the electrician will complete the work, and then the city inspector may review the work. Following approval from the city inspector, when required, the utility field crew will come out the site and install the second meter.

The process is the same for the customer's electrician to install a charging station. However, the required permits may differ and the permit cost may be more expensive. The availability and work schedule of electricians, availability of city inspectors, and scheduling with the utility each influence the amount of time this process can take. Typically, the process will take at least several weeks and could take longer.

#### 4.6.1.2 Utility Perspective

The costs to the utilities include the meter itself and the associated labor to install and maintain it. The combined cost of the meter and labor varied significantly by utility, and may be partially attributable to the different cost accounting methods at each utility. The combined meter and labor costs ranged from \$120 to \$388, with an average cost of \$219. Under the separate utility revenue-grade meter scenario the utilities already have billing systems and processes in place, so there are no incremental system costs to the utility.

### 4.6.2 Service Model 2: Cost of Installing a Submeter at Full Scale with Automation

In Service Model 2, which a customer installs a charging station to separately meter their PEV, there are several costs to the customer and utility. The primary cost components for the customer include the charging station and the cost related to installation. From the utility perspective the primary costs include billing system upgrade costs and the administrative cost to establish a long-term program.

<sup>82</sup> <https://www.homeadvisor.com/cost/garages/install-an-electric-vehicle-charging-station/#>. Installation costs were averaged across the cities of Berkeley, Burbank, Sacramento, San Diego, and San Jose. The lowest average cost was \$433 in Sacramento and the highest average cost was \$706 in San Jose.

<sup>83</sup> SDG&E does not have a meter charge. SCE meter charge per month is \$2.76. Source: <https://www1.sce.com/NR/sc3/tm2/pdf/ce114-12.pdf>. PG&E charges \$0.049 per day, which is approximately \$1.47 per month. Source: [https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC\\_SCHEDULES\\_EV%20\(Sch\).pdf](https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_EV%20(Sch).pdf)

Table 4-22 presents the cost estimate for a customer to install a charging station with an integrated submeter. Under a full scale utility program without incentives, a customer can expect to pay approximately \$1,250 to purchase and install a charging station with integrated submeter. Table 4-23 presents the one-time and recurring costs that are expected to be incurred by the utilities to achieve full scale automated billing operations incorporating third-party submeter data. The average one-time cost per utility is approximately \$4,200,000 and the expected annual recurring cost per submeter is approximately \$200.

The following sections provide the underlying details that were used to develop the estimates for the customer and utility perspectives.

**Table 4-22: Service Model 2-Customer Cost of Installing a Submeter**

Paid By:	Cost Component	Average	Range
<b>Customer</b>	Charging Station w/ Submeter	\$650	\$500 to \$850
	Charging Station Installation Related Costs	\$616	\$384 to \$866
	Utility Incentives to MDMA, Passed on to Customer	-\$400	N/A
	<b>Total Cost to Customer (With Pilot Incentive)</b>	<b>\$866</b>	<b>\$484 to \$1,316</b>
	<b>Total Cost to Customer (Without Pilot Incentive)</b>	<b>\$1,266</b>	<b>\$884 to \$1,716</b>

**Table 4-23: Service Model 2-One-Time & Recurring Utility Cost of Submetering at Full Scale with Automation**

Cost Type:	Cost Component	Average	Range
<b>One-Time / Per Utility</b>	Cost to Establish Protocols	\$357,500	\$215,000 to \$500,000
	Updating Systems for Full Billing/Data Automation	\$3,833,333	\$3,000,000 to \$4,500,000
	<b>Total One-Time Cost to Utility</b>	<b>\$4,190,833</b>	<b>\$3,215,000 to \$5,000,000</b>
<b>Recurring / Per Submeter</b>	Operations & Administration Labor Costs per Submeter	\$198	\$50 to \$346
	<b>Total Annual Recurring Cost to Utility per Submeter</b>	<b>\$198</b>	<b>\$50 to \$346</b>

Table 4-24 presents the total costs to the customer and utility at full scale with automation per submeter. To generate these numbers, we made several assumptions regarding customer participation and the length of time to amortize one-time utility costs. The participation rate used in this scenario was 10,500 customers per utility in 2022.<sup>84</sup> This participation rate is an average across the utilities based on the utility provided participation forecast.

Costs are assumed to be spread across three years. The average utility one-time cost per customer is calculated by dividing the total one-time cost per utility of \$4,190,833 by 3 years, which equals \$1,396,944. This number is then divided by the customer participation forecast of 10,500 to reach the value of \$133.<sup>85</sup>

<sup>84</sup> 2022 is used as an example year after all system upgrades could be completed across all utilities and represent a year with fully operational programs.

<sup>85</sup> The vast majority of customers only install one submeter. Therefore, the customer and submeter forecast are identical for this analysis.

This analysis is sensitive to both the participation rate and the number of years over which the costs are allocated and reviewers may test different assumptions by revising the calculation above. The final outcome of this exercise is a total cost to customers and the utility of approximately \$1,600 per customer in 2022.<sup>86</sup>

**Table 4-24: Service Model 2-Total Cost of Submetering at Full Scale with Automation per Submeter**

Cost Type:	Cost Component	Average	Range
<b>Customer: One-Time</b>	Total Cost to Customer Without Pilot Incentive	\$1,266	\$884 to \$1,716
<b>Utility: One-Time</b>	Average cost per customer assuming 10,500 customers per utility in 2022, spreading one-time costs over 3 years	\$133	\$102 to \$159
<b>Utility: Recurring</b>	Total Annual Recurring Cost to Utility per Submeter	\$198	\$50 to \$346
<b>Total Costs</b>	<b>Total One-Time Cost to Customer &amp; Utility</b>	<b>\$1,399</b>	<b>\$986 to \$1,875</b>
	<b>Total One-Time + Recurring Cost to Customer &amp; Utility in 2022</b>	<b>\$1,597</b>	<b>\$1,036 to \$2,221</b>

#### 4.6.2.1 Customer Perspective

The primary costs to the customer under the submetering service model include the purchase and installation of a charging station with integrated submeter. The average cost for a charging station with integrated submeter in this pilot was \$650 retail. Prices in the pilot ranged from \$500 to \$850 based on the brand and features.<sup>87</sup> Installation costs for the charging station are the same as the separately metered service model (approximately \$600) as described in Section 4.6.1.1 and will vary based on location and existing wiring infrastructure.

The average cost of a non-networked charging station is approximately \$450 and a charging station from this pilot with an integrated submeter averaged about \$650, resulting in a difference of approximately \$200. The primary difference between the charging station costs in the submetering service model compared to the separate utility-grade meter service model is the integration of the submeter and Wi-Fi connectivity of the charging station. Of course, a customer could purchase a network connected charging station in the separate utility-grade meter service model as well. However, a network connected charging station is optional under the separate utility-grade meter case, and required under the third-party submetering service model in this pilot.

In the pilot, customers were able to earn up to \$400 in incentives through the MDMA<sup>88</sup> if they stayed in the pilot for a full 12 months. With the incentive, the average customer is expected to have spent approximately \$850 for the charging station and installation. Without the incentive, a

<sup>86</sup> At this time it is unknown how the utility costs would be allocated across customers.

<sup>87</sup> From MDMA correspondence: Kitu (approximately \$550), eMotorWerks (\$849 at the pilot start, \$749 by the end of the enrollment period), ChargePoint (\$500-\$700, depending on which station they purchased)

<sup>88</sup> Utilities provided \$210 per enrolled customer and \$17.50/month for MDMA services / submeter. These fees were not required to be forwarded to the customer. The MDMA<sup>s</sup> provided up to \$400 to customer in incentives.

customer would have paid approximately \$1,250 for the charging station and installation. Under a full scale submetering program, it is unknown if customer incentives would still be available, or if they would be similar to what was offered under the pilot.

eMotorWerks indicated that they would consider bearing incentive costs to induce participation depending on likely sales volumes due to a submetering program. For example, they offer \$50 rebates to customers who sign up for their smart charging/demand response program. They also noted that depending on the level of monthly service revenue and availability of demand response participation from submetered customers, they would consider a monthly contract. This approach would allow them to provide the charging station, installation, and submetering service for little or no money down. Incentives and or payment arrangements such as those described by eMotorWerks may help to lower the initial cost outlay and encourage more customers to install a Level 2 charging station at their home.

To install a charging station a customer would typically hire a licensed electrician. The electrician would come out to the premise and determine the work needed to install the charging station. Prior to commencing the work, the electrician needs to obtain a permit from the city or local jurisdiction. Once the permits are obtained, the electrician will complete the work, and then the city inspector may review the work. Typically the complete process will take days to weeks based on the availability and work schedule of electricians, and availability of city inspectors, as required.

#### 4.6.2.2 Utility Perspective

Utility costs fall within two categories: one-time costs, and annual recurring costs. The one-time costs include establishing the submetering protocols and updating the billing systems for third-party submeter data integration. Annual recurring costs include administrative labor costs to operate the program, address customer inquiries, and rebill customers for missing or incomplete data.

To establish the submeter protocols, each utility expects to incur costs related ranging from \$215,000 to \$500,000. These costs include time for internal staff, stakeholder workshops, and potentially the need to hire external consultants to provide subject matter expertise. Cost estimates to update the data and billing systems range from \$3,000,000 to \$4,500,000 per utility.

These costs include but are not limited to:

- Establishing MDMA accessible folder structures;
- Creating appropriate codes to identify the MDMAs, manufacturer and model codes, and meter type codes within the utility server infrastructure;
- Creating gateway for the meter data management system (MDMS) to take in a flat file of interval usage data from the MDMA;
- Developing processes for collecting the MDMA data and moving to a staging folder for aggregation and processing;
- Creating a new interface program that will pick up the MDMA-Reported Interval Data from the staging folder and review the data for acceptance or rejection;
- Transferring records passing validations to the MDMS gateway for consumption by the MDMS;

- Performing administrative tasks in support of the new submeters and validation, estimation, and editing rules;
- Developing and implementing enrollment and un-enrollment automation tasks;
- Developing rules for NEM billing; and
- Reconciling direct access (DA) and CCA processes within the billing system.

Several factors may affect the accuracy of the cost estimates that include but are not limited to:

- Protocols<sup>89</sup> that establish the data standards: without issues such as data quality, format, and delivery frequency agreed upon, it leaves uncertainty regarding the design needs, and subsequent costs, for the system.
- Data quality from MDMA: automation upgrades can be implemented, but they do not resolve the problem of inaccurate metering and MDMA data processing. If submeter energy usage continued to be inaccurate, that would result in a variety of customer complaints and costly resolution steps when scaled across all of a utility's systems (billing, call center, etc.).
- Timing: SCE and SDG&E are undergoing major billing system upgrades over the next few years. The timing of implementing the automation may affect the cost of the project due to the uncertainty related to costs expected several years out under systems that have not yet been implemented.
- Potential requirements for inclusion of customer facing applications like MyEnergy, FirstFuel, and Opower, or rate analysis tools: Requirements for customer facing applications have not been established, and will add cost if they must be implemented.

The annual recurring costs varied significantly by utility. Estimates for these costs ranged from \$50 per submeter up to nearly \$350 per submeter per year. These costs include the utility program staff that will operate the program, along with charges for time from the billing and call center staff that will be supporting the operations. The variation in these costs may be attributable to how costs are allocated across organizations within a utility, the number of participating customers, and underlying assumptions regarding the frequency and type of interactions with customers. Data quality from the MDMA, the need for customer facing applications, and the division of labor between MDMA and utilities from a customer service perspective will also heavily influence the costs.

#### 4.6.3 Comparing Service Models 1 and 2

This section provides a cost comparison from the customer, utility, and total cost perspectives. The customer perspective explores differences in installation costs, energy related costs, and the payback period under the different service models including whole-house rates without separate metering for PEV charging. The utility perspective compares the cost per submeter from the pilot to the expected cost per submeter at full utility scale with automation in order to understand the potential for cost efficiencies. The total cost perspective reflects the differences in total cost that can be achieved at scale.

<sup>89</sup> A protocol could increase or decrease utility costs. SDG&E is currently more automated than the other utilities. If a protocol resulted in a different data format compared to what they currently use, they would incur costs to change their system to accept a different format.

### 4.6.3.1 Customer Perspective

#### Installation Costs

The installation cost estimate of Service Model 1 (separate utility revenue grade meter) is \$1,640. The installation cost estimate under Service Model 2 (charging station with submeter) is \$1,266. This results in a cost difference of \$374, not including the pilot incentive. Both installations require the addition of a circuit from either the primary or secondary panel to the charging location.<sup>90</sup>

The primary difference between the two options is that installing a separate utility-grade meter requires the addition of a new panel and associated installation costs, whereas the submeter approach requires the purchase and installation of a charging station with an integrated submeter. From the customer's perspective, the charging station with submetering capabilities from Service Model 2 is the lower cost option even without factoring in the possibility of program incentives.

#### Energy Costs

Nexant conducted a billing analysis to understand how customer costs are affected by various rate structures with and without separate metering of PEV charging. Five different rate structures were analyzed:

- Tiered;
- Default<sup>91</sup> whole-house TOU;
- Whole-house TOU for PEV charging;
- Separately metered PEV charging with a household tiered rate; and
- Separately metered PEV charging with a household default TOU rate.

Whole-house TOU rates are included in this analysis because they can also encourage off-peak charging and have the potential to reduce customer bills through lower cost off-peak prices relative to a tiered rate. Whole-house TOU rates are relevant to this analysis because millions of residential customers in California will be transitioned to TOU rates beginning in 2019. The three utilities will be transitioning the majority<sup>92</sup> of their customers onto TOU rates unless the customers take steps to opt out. SDG&E will start transitioning customers in March of 2019 and PG&E and SCE are expected to start their customer transitions in 2020.

In order to develop the analysis, several assumptions related to miles driven and PEV energy consumption per mile were necessary. We assumed a customer drives 12,000 miles<sup>93</sup> per year, which is a typical annual mileage limit for an auto lease. This works out to approximately 33

<sup>90</sup> SCE recently implemented the Charge Ready Home Installation Rebate Program where residential customers can receive a rebate of up to \$1,500 toward their out-of-pocket costs for the electrical upgrades and permitting fees necessary to allow installation of a Level 2 (240-volt) PEV charging station. The rebate does not cover the cost of the charging stations, but it will help cover the cost of installing and permitting the charging station.

<sup>91</sup> The rate used in this analysis was the 4 PM to 9 PM peak period rate customers are being defaulted into in the SCE default TOU pilot.

<sup>92</sup> Income qualified customers on programs such as CARE or FERA who live in hot climate regions are exempt from this transition.

<sup>93</sup> Other mileages could be evaluated, but the same mileage is used in all scenarios so the specific mileage used does not affect the relative differences between scenarios.

miles per day. We then examined the efficiency of PEVs by calculating the average kWh per mile across the Chevy Bolt, Nissan Leaf, and Tesla Model 3. The calculations were based on battery capacity and range data found at EVadoption.com.<sup>94</sup> All three of the vehicles showed similar efficiency, ranging from 0.25 kWh per mile for the Bolt and Model 3 to 0.28 kWh per mile for the Leaf. An average of 0.26 kWh per mile was used in the simulation calculations, and resulted in a daily charging need of 8.62 kWh to drive 33 miles. The estimate of electricity consumption on a monthly basis needed for charging is 259 kWh (30 days x 8.62 kWh per day).

Table 4-25 presents the lowest cost per kWh across a variety of rate types by utility. This pricing data was used to develop the cost estimate of driving a PEV 33 miles per day and charging a total of 259 kWh per month presented in Table 4-26. From a PEV charging cost perspective, the PEV specific rates are the lowest cost compared to the more typical tiered or default TOU rates. However, the separately metered PEV rate requires the cost of installing the separate utility-grade meter or the purchase and installation of a charging station. The tradeoff with the whole-house PEV TOU rate is the high cost of on-peak electricity usage.<sup>95</sup>

**Table 4-25: Lowest Cost for Charging per kWh by Rate Type (Summer)<sup>96</sup>**

Rate Type	PG&E	SCE	SDG&E
Separately Metered PEV TOU (Off-peak or Super Off-Peak)	\$0.13	\$0.13	\$0.23
Whole-House PEV TOU	\$0.12	\$0.12 <sup>97</sup>	\$0.23
Residential Default TOU (Off-peak or Super Off-Peak)	\$0.32	\$0.22	\$0.36
Residential Tiered (Non-TOU) Rate (50/50 Tier 2 & High Usage)	\$0.36	\$0.30	\$0.51
Residential Tiered (Non-TOU) Rate- Tier 2 (101%-400%)	\$0.28	\$0.25	\$0.47
Residential Tiered (Non-TOU) Rate- High Usage (>400%)	\$0.44	\$0.35	\$0.55

**Table 4-26: Cost Estimate of Charging for 259 kWh per Month (Summer, 33 Miles per Day)**

Rate Type	PG&E	SCE	SDG&E
Separately Metered PEV TOU (Off-peak or Super Off-Peak)	\$33.67	\$33.67	\$58.66
Whole-House PEV TOU	\$31.08	\$31.08	\$58.66
Residential Default TOU (Off-peak or Super Off-Peak)	\$82.88	\$56.98	\$93.76
Residential Tiered (Non-TOU) Rate (50/50 Tier 2 & High Usage)	\$93.98	\$77.70	\$132.09
Residential Tiered (Non-TOU) Rate- Tier 2 (101%-400%)	\$73.76	\$64.75	\$121.73
Residential Tiered (Non-TOU) Rate- High Usage (>400%)	\$114.21	\$90.65	\$142.45

<sup>94</sup> <http://evadoption.com/ev-statistics-of-the-week-range-price-and-battery-size-of-currently-available-in-the-us-bevs/>

<sup>95</sup> Examples of the on-peak rates are included in Appendix I.

<sup>96</sup> See Appendix I for the documentation of the tariffs used to develop the table.

<sup>97</sup> SCE does not currently offer a PEV specific whole-house TOU rate. The Schedule TOU-D Option A was used in this example as the rate most similar to the PG&E whole-house PEV specific TOU rate. Both have on-peak rates of \$0.47 or 0.48 and off-peak rates of \$0.12 or \$0.13 per kWh.

To understand the tradeoffs between the low off-peak rate and the high on-peak rate it is important to evaluate the total cost of electricity and not only the PEV charging portion. This is particularly important due to the nature of the current tiered rate structure and forthcoming default TOU rates in California. Under the tiered rate structure the addition of PEV charging may push a customer into a higher tier. Whole-house PEV rates that provide a low off-peak price often have a high on-peak price which could be expensive for customers in hot climate regions who use air conditioning.

To understand the billing impacts from household energy usage and PEV charging, we estimate the total annual cost under the five rate structures. Hourly customer energy usage data from the CA Statewide Opt-in Residential TOU Pilot<sup>98</sup> was used as the basis for estimating the bills. With hourly electricity data, it was possible to layer the charging data on top of the regular household consumption data and then calculate the average customer's annual energy cost for the home and the PEV charging. This billing analysis is provided as an example for one customer segment at SCE. However, the outcomes are specific to that population, and not generalizable to the full population at SCE or the other utilities. As discussed below, a much larger comprehensive billing analysis based on customers known to have PEVs would help to better understand the distribution of bill impacts on various rates.<sup>99</sup>

Table 4-27 presents the outcomes from the billing simulation.<sup>100</sup> The tiered rate structure for the whole-house is the highest cost to customers from an annual electricity cost perspective (\$2,156.07). Separate PEV charging metering with the general household energy consumption on a tiered rate was the lowest cost option (\$1,778.52)—not factoring in the one-time costs for either type of separate metering—with an estimated savings of \$378 per year relative to the tiered rate.

Interestingly, this hypothetical customer could save \$319 per year relative to the tiered rate by enrolling on a whole-house rate for PEV charging<sup>101</sup> (\$1,837.30) and not need to invest in any type of separate metering. To test the sensitivity of the whole-house rate design, PG&E's whole-house PEV TOU EV-A rate specifications were substituted into the model. The changes to the peak hours and higher peak period prices on the weekends resulted in an annual cost of \$2,141.81, which is very similar to the annual costs on SCE's tiered rate. This is an important observation because both rates have peak period prices of \$0.47 or \$0.48 per kWh and off-peak prices of \$0.12 or \$0.13 per kWh, yet produce very different outcomes.

The cost comparisons presented thus far have shown how much a customer could save by switching to a lower cost rate from the tiered rate. However, the incremental benefit of separate metering is best presented by comparing the lowest annual cost on a rate without separate metering to the lowest annual cost on a rate with separate metering. In this example, the lowest cost rate without separate metering is the "Whole-House TOU Rate for PEV Charging" with an

<sup>98</sup> <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442457172>. Summer and winter hourly usage data for customers in the moderate climate region on the average weekday at SCE were used for this analysis. See Appendix I Table AI-4 for the supporting assumptions and calculations.

<sup>99</sup> The type of sophisticated billing analysis conducted for the CA Statewide Residential TOU pilots required hundreds of hours to complete and was not in scope for this pilot evaluation.

<sup>100</sup> See Appendix I for assumptions and calculations.

<sup>101</sup> This rate was SCE's TOU-D-Option A, which is not specifically at PEV rate. It was used because SCE does not have a specific whole-house PEV rate, but it was reasonably close to the design of PG&E's EV-A rate which is a whole-house PEV rate.

average annual cost of \$1,837.30. The lowest average annual cost under a rate with separate metering is \$1,778.52 on the “Separate PEV Rate + Household Tiered Rate.” The difference of \$58.79 is the incremental annual savings associated with the separate meter enabled rate.

The potential cost savings of switching from a tiered rate to a whole-house PEV rate indicates that significant savings may be achieved without separate metering. However, based on the sensitivity analysis, we can see the rate structure is an important factor in determining the outcome. It is important to note this analysis was based on average customer usage in SCE’s moderate climate region, which was derived from an underlying distribution of actual customer usage data. A customer’s energy use patterns and location (utility, climate, and associated baseline allocation) will all affect the outcome.

**Table 4-27: Estimates of Household Use plus PEV Charging Annual Electricity Cost**

Rate Type	Annual Cost
SCE Tiered Rate	\$2,156.07
SCE Default Whole-House TOU Rate	\$1,997.43
SCE Whole-House TOU Rate for PEV Charging <sup>101</sup>	\$1,837.30
SCE Separate PEV Rate + Household Tiered Rate	\$1,778.52
SCE Separate PEV Rate + Household TOU Rate	\$1,818.99
PG&E Whole-House TOU Rate for PEV Charging	\$2,141.81

While the results above may represent the average customer in SCE’s moderate climate region, they are not specific to PEV owners, who may have different energy use patterns. Many households would have a problem on a whole-house PEV rate due to the need for end uses like air conditioning. These findings tell us that some customers may benefit from a whole-house PEV rate, but each customer should conduct a rate analysis to determine what is optimal given their energy usage trends.

It would be beneficial to develop a comprehensive billing analysis similar to what was conducted in the CA TOU pilots to better understand the distribution of bill impacts under various scenarios rather than the average impact. Two key pieces of additional information would be needed to conduct a rigorous analysis:

- The geographic distribution of PEV owners within each utility’s service territory to properly account for climate differences and baseline allocations; and
- At least one year of hourly consumption data from PEV owners separately tracking household energy usage and charging data on a sufficiently large sample of customers.

With this information it would be possible to develop a comprehensive understanding of energy cost tradeoffs between whole-house and separately metered PEV charging rates.

### **Payback Period**

The payback period for a customer investment can be determined by comparing the expected installation costs with expected customer bill savings. Based on the annual energy cost savings estimates, a customer could save approximately \$378 a year by moving from a tiered rate to a separately metered rate. Under Service Model 1 (separate utility revenue grade meter

scenario), the installation cost is estimated at \$1,640. With an annual benefit of \$378, the payback period for the investment is 4.3 years ( $\$1,640 / \$378 = 4.3$ ). However, a significant portion of the annual savings (\$319) could be realized by switching from a tiered rate to a whole-house PEV rate and the cost of installing a separate meter or submeter could be avoided. The payback period from the incremental benefit<sup>102</sup> of \$59 ( $\$378 - \$319 = \$59$ ) under a separately metered rate is significantly longer at 27.8 years ( $\$1,640 / \$59 = 27.8$ ).

Under Service Model 2 (charging station with submeter scenario), the payback period of switching from a tiered rate to a submeter enabled TOU rate is 3.5 years ( $\$1,266 / \$378 = 3.5$ ). Service Model 2 provides the same incremental benefit of \$59 as Service Model 1. Accordingly, the payback period from the incremental benefit under Service Model 2 and a separately metered rate is 21.5 years ( $\$1,266 / \$59 = 21.5$ ). Based on these payback outcomes, a customer should generally prefer the Service Model 2 submeter approach if all else is held equal.<sup>103</sup> This exercise provides an example of an average customer in the moderate climate region in Southern California. There are hundreds of possible combinations of utility rates, climate regions, and baselines that will all affect the outcomes of a similar simulation. Customer energy usage behavior is also an important factor in determining the potential for savings and the payback periods for an individual customer's investment. Consequently, the payback period may vary significantly on a customer by customer basis.

#### 4.6.3.2 Utility Perspective

Table 4-24 provides the estimated average cost per customer to utilities under Service Model 2 with submetering at full scale with automation. The one-time cost spread across three years is \$133 per submeter per year. Utilities estimate an additional \$198 per submeter per year will be necessary to operate and administer the program. This results in total cost of \$331 per submeter per year in the comparison year 2022. As noted previously, changing the enrollment forecast or number of years over which the cost is spread can change these cost figures significantly.

Table 4-21 provides the current average utility cost to provide and install a separate utility-grade meter under Service Model 1. The cost of \$219 is one-time, and the customers may pay a fee of up to \$2.76 per month for the meter.<sup>104</sup> Under the pilot, the average cost per submeter to the utility<sup>105</sup> was \$3,100 as shown in Table 4-28. The pilot cost per submeter per year was influenced by the customer participation rate. Many of the pilot costs such as administrative labor could have been spread across a greater number of submeters, lowering the average cost per submeter, had the participation rates been higher.

<sup>102</sup> Cost savings of switching from the lowest cost whole-house rate to the lowest cost rate enabled by separate metering.

<sup>103</sup> Meaning the level of service to the customer is comparable between the two options. Timely and accurate bills are a key factor.

<sup>104</sup> SDG&E does not have a meter charge. SCE meter charge per month is \$2.76.

Source: <https://www1.sce.com/NR/sc3/tm2/pdf/ce114-12.pdf>

PG&E charges \$0.049 per day, which is approximately \$1.47 per month.

Source: [https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC\\_SCHS\\_EV%20\(Sch\).pdf](https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHS_EV%20(Sch).pdf)

<sup>105</sup> This calculation was based on data provided by PG&E and SCE. SDG&E did not provide this data.

**Table 4-28: Total Cost per Submeter from Pilot**

Cost Type:	Cost Component	Average
<b>Customer: One-Time</b>	Customer Cost for Charging Station & Installation with Incentive	\$866
<b>Utility: One-Time</b>	Average annual utility pilot cost per submeter	\$3,100
<b>Total Cost</b>	<b>Total Cost per Submeter to Customer &amp; Utility</b>	<b>\$3,966</b>

During the years where the one-time costs for establishing full scale utility submetering are allocated, the costs are significantly higher for submetering compared to the one-time costs to the utility for installing a second meter. However, even on an ongoing basis after the one-time costs have been paid there are still significant costs to administer and operate the program estimated to be \$198 per year per submeter. A primary difference from the utility perspective is the separate utility-grade meter service model does not require the program administration and operations costs because it is already integrated with the billing systems.

The cost per submeter to continue submetering without investing in the utility billing system changes is unknown. If the pilot were to be continued and expanded, it seems reasonable the cost per submeter would likely fall. However, there is a point after which the costs would begin to increase due to the lack of automated systems. Should submetering continue, customer participation rates will be an important factor in the cost effectiveness of the program.

#### 4.6.3.3 Total Cost Perspective

Under the pilot, the total cost to customers and the utility per submeter was \$3,966 as shown in Table 4-29. Under a Service Model 2 submetering program the total cost to customers and the utility per customer in 2022 is expected to be \$1,597. This reflects a cost efficiency expected from the investment in the utility billing system automation. However, this estimate is also based on assumed participation levels of 10,500 customers per utility. The pilot costs would have been lower per submeter had there been greater levels of participation.

Conversely, the costs per submeter could be higher under the submetering at full scale with automation scenario if there is not sufficient customer interest. The Service Model 1 separate utility-grade meter with no charging station is more expensive than Service Model 2 submetering at full scale from the total cost to customers and the utility perspective. However, the cost difference is highly dependent on the submetering participation rates and other factors as discussed above.

**Table 4-29: Estimate of Total Cost to Customers and Utility per Meter by Scenario**

Scenario	Cost Estimate
Submetering Annual Cost in Phase 2 of the Pilot	\$3,966
Service Model 1: Separate Utility-Grade Meter with No Charging Station	\$1,859
Service Model 2: Submetering at Full Scale with Automation in 2022	\$1,597

It is unclear if MDMA's would offer submetering services without incentives or compensation from the utility. Nexant requested pilot operating cost data from the MDMA's in order to understand the type and level of costs related to providing the submetering service. The MDMA's responded that their cost data was proprietary and were unwilling to share. There is no question that costs are involved in offering the submetering service. However, what those costs are, and who pays for them, will be an important issue related to the success of this business

model. Customers can achieve significant annual savings<sup>106</sup> through submetering relative to a traditional utility rate, so presumably some customers would be willing to pay a fee for the submetering service in order to save money.

#### 4.6.4 Cost Estimation Summary

CPUC decision D.13.11-002 established cost related data collection and analysis requirements. The two primary cost related requirements included evaluation categories 1 and 9, listed below:

*1. Comparison of the total cost of metering services. Metering, electrical equipment and labor cost; installation time and processes; fixed, energy and/or demand costs; number of PEVs participating and miles driven. Compare total cost for submetering to (a) separate PEV metering and (b) Submeter Scenario 1.<sup>107</sup>*

*9. Cost minimization. Costs incurred by pilot administrators in labor, incentives, equipment, manual billing and service operations. Estimation of budget requirements for Phase 2 testing Multiple Customers of Record. Estimation of potential changes in costs per customer, at scale, achieved through billing automation.*

This section summarizes the outcomes within the framework of the requirements listed above and provides evidence the pilot evaluation sufficiently addresses the cost comparison questions.

##### 1. Comparison of the total cost of metering services.

- a. Metering, electrical equipment and labor cost;
  - i. The estimated total cost to customers and utility per meter is \$1,859<sup>108</sup> under Service Model 1 (separate utility-grade meter), and \$1,597<sup>109</sup> under Service Model 2 (third-party submetering at full scale) in 2022.
- b. Installation time and processes;
  - i. The installation time of a Service Model 2 charging station with submeter typically ranges from days to weeks given the need for permits and city inspection. A Service Model 1 separate utility-grade meter installation is expected to take longer given the additional steps involving the utility. The processes are explained in the previous customer perspective sections.
- c. Fixed, energy and/or demand costs;
  - i. Table 4-27 provides annual electricity cost estimates under a variety of rates. Cost estimates based on the provided assumptions show a customer could save \$378 per year by changing from a tiered rate to a separately metered PEV charging rate. However, a customer could also save \$319 by switching from a tiered rate to a whole-house PEV rate and avoid the cost of installing a separate meter or submeter. The incremental

<sup>106</sup> Annual energy cost savings is discussed in Section 4.6.3.1.

<sup>107</sup> Submeter Scenario 1 from the decision is represented by Service Model 2 in the sections above.

<sup>108</sup> See Table 4-21 for source data.

<sup>109</sup> See Table 4-24 for source data.

benefit of a rate enabled by separate metering was estimated at approximately \$59 per year.<sup>110</sup>

- d. Number of PEVs participating and miles driven.
  - i. 449 submeters were installed in Phase 2 of the pilot. Survey responses indicate that 87% of customers owned 1 PEV, 12% of customers owned 2 PEVs, and 1% of customers owned 3 PEVs. Based on this information it is expected that approximately 511 PEVs participated. Cost based calculations were based on an assumption<sup>111</sup> of 12,000 miles driven per year.
- e. Compare total cost for submetering to (a) separate PEV metering and (b) Submeter Scenario 1.
  - i. Table 4-29 presents the estimate of total cost to customers and utility per meter by service model. Based on the assumptions described in the related cost estimation sections the total estimated cost per meter of a Service Model 1 separate utility-grade meter with no charging station is \$1,859 and the cost estimate per meter for Service Model 2 submetering at full scale with automation in 2022 is \$1,597.

## 9. Cost minimization.

- a. Costs incurred by pilot administrators in labor, incentives, equipment, manual billing, and service operations.
  - i. The average annual cost per submeter from the pilot was \$3,100 as described in Section 4.6.3.2.
- b. Estimation of budget requirements for Phase 2 testing Multiple Customers of Record.
  - i. MCOR was not included in Phase 2 of the pilot.
- c. Estimation of potential changes in costs per customer, at scale, achieved through billing automation.
  - i. The cost per submeter is expected to decrease by 60% (\$2,369) from \$3,966 per submeter in Phase 2 of the pilot to \$1,597 under Service Model 2 with billing automation in 2022.<sup>112</sup> In subsequent years when the one-time costs have been paid there will be additional savings of \$133<sup>113</sup> per submeter.

<sup>110</sup> The billing analysis was provided as an example for one customer segment at SCE. However, the outcomes are specific to that population, and not generalizable to the full population at SCE or the other utilities. As discussed, a much larger comprehensive billing analysis based on customers known to have PEVs would help to better understand the distribution of bill impacts on various rates.

<sup>111</sup> Annual mileage was not collected via the surveys.

<sup>112</sup> See Table 4-29 for source data.

<sup>113</sup> See Table 4-24 for source data.

# 5 Conclusions

## 5.1 Key Findings

Phase 2 of the PEV Submetering pilot established third-party submetering service for 449 customers throughout California using submeters embedded in PEV charging stations. The primary motivations for customers to participate in the pilot were the opportunity to save money on PEV charging, and to save money on a charging station.

The MDMA's were responsible for recruiting customers to the pilot; providing, installing, and operating the submetering equipment; and delivering the PEV charging data to the utilities. The utilities were responsible for receiving data from the MDMA's, calculating the electricity used for charging, and providing bills to the customers based on the submetering results.

The majority (81%) of participants surveyed at the beginning of the pilot said that they were "extremely satisfied" (46%) or "somewhat satisfied" (35%) with the service to that point. At the end of Phase 2 (after 12 months of service), 91% of customers said that they were "extremely satisfied" or "somewhat satisfied" and nearly all (94%) of the pilot participants indicated that they would like to continue the service if they could do so. Almost all of the customers said that they believed that such a program would be an important service for the utility to offer.

So, a key take away from the pilot is that participating customers enjoyed the benefits of the submetering service; would recommend it to friends; and think it is something the utilities should offer to customers.

While the vast majority of customers were satisfied with the service they received during the pilot, some were not. Approximately 10% of customers (42) discontinued participation during the pilot. When asked why they were leaving, the two most frequently cited reasons were "Not enough bill savings" and "Other billing problems." Another 4% of customers (13) continued to participate in the pilot but indicated they were dissatisfied with the service they received during the pilot.

Of the 13 respondents who reported being dissatisfied at the end of the pilot, 3 stated that billing accuracy was the most important factor leading to their dissatisfaction, while 3 others stated that an increase in their electricity cost was the most important reason for their dissatisfaction. The remaining dissatisfied customers were displeased by a variety of customer service issues.

Billing issues experienced by Phase 2 participants were caused by several related problems. Usage data supplied by one of the MDMA's was not formatted in the manner the utilities expected, which caused data supplied by this MDMA to be rejected by the utilities. This problem was quickly resolved at the beginning of the pilot.

In addition, in some cases, charging data was not supplied by the MDMA's to the utilities in a timely manner. When this happened, customers received late bills or bills that did not reflect their PEV charging. Nexant could not determine the exact cause of these data stream interruptions, but it appears that they were mostly explained by failures in the Wi-Fi systems connecting submeters to the internet. The utilities also judged the incoming PEV charging data to be "failed intervals" if submetering loads during a given interval exceeded the whole-house loads measured at the smart meter. Failed intervals could also be caused by NEM customers who charged their PEV during generation. When this occurred, their PEV charging kWh exceeded their net kWh (total household kWh including PEV charging – generation kWh)

resulting in failed intervals.<sup>114</sup> In these cases, the usage from the submeter was not netted out of the whole-house load and the customer may have received a higher bill than they should have for charging their vehicles.<sup>115</sup>

To evaluate the accuracy of submeters, Nexant compared usage data from a sample of submeters to consumption measurements from data loggers installed on the household electrical systems directly upstream of the submeters. Our evaluation revealed that only 5% of the submeters met required standards for accuracy. The analysis was repeated using daily consumption levels rather than the 15-minute intervals to determine if the submeters were missing the accuracy target because of a minor difference in time syncing between the submeters and the loggers. At the daily level, less than 10% of the submeters passed within a  $\pm 2\%$  threshold. The accuracy threshold for the field measurements was further increased to  $\pm 5\%$  at daily intervals to account for the possibility that line losses between the loggers and submeters were responsible for the apparent differences in consumption measurements. Even at this relaxed threshold of performance only about 20% of the submeters passed the accuracy testing standard.

Upon discovering the low level of accuracy in the data delivered to the utilities from the field, stakeholders decided to investigate the acceptance accuracy of the submeters using an independent third-party laboratory. The laboratory conducted additional submeter accuracy testing using the  $\pm 1\%$  accuracy standard required in Phase 2 of the pilot and found that none of the submeters they tested met this standard.

Nexant also conducted a cost evaluation, showing that it is at least \$350 less expensive for a customer to install a charging station with a submeter than it is to install a separate utility-grade meter.

In addition, an analysis of the customer cost of vehicle charging shows that customers can benefit significantly from paying for PEV charging at a dedicated PEV-TOU rate supported by separately metered service. However, in order to scale this pilot, our research found that utilities will need to make significant IT systems investments of approximately \$3 to \$4.5 million per utility.

A full cost benefit analysis will require reaching a consensus on the part of the utilities and CPUC regarding the economic value of benefits of separately metered PEV charging.

## 5.2 Conclusions and Recommendations

Participating in the PEV Submetering Pilot caused participants to charge their vehicles off-peak. In addition, almost all of the customers in the pilot were highly satisfied with submetering and would continue receiving this service if allowed to do so.

However, submeter accuracy, MDMA data formatting, and timely transmission of data caused significant problems for both utilities and some customers during the pilot. For this reason, Nexant believes further work is necessary to resolve these problems before submetering can be offered more broadly.

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<sup>114</sup> See Footnote 72. Interestingly, for NEM customers this could lead to a lower cost for PEV charging. This is discussed in greater detail in Section 4.4.3.3.

<sup>115</sup> The approach used in addressing the failed intervals is consistent with the tariff at each utility.

Nexant finds that all parties (MDMAs, utilities, and customers) would benefit from further refinement of the submeter acceptance testing standard. We also find that, given the demonstrated weaknesses in the communications links between the submeters and the MDMAs (i.e., Wi-Fi to internet), it is important that a quality control standard be developed to ensure that accurate data is delivered to the utilities.

Although the MDMAs involved in the pilot were required to submit performance verification documents, acceptance testing by PG&E and a third-party testing laboratory found that the submeters did not meet the minimum performance standards. These results suggest that there is either substantial submeter-to-submeter variation in accuracy; or slight variations in the testing protocols can lead to very different conclusions about submeter accuracy. Either way, we are left with uncertainty about the accuracy of the submeters. Considering this situation, Nexant recommends that:

1. A performance verification protocol should be developed and published. This protocol should include specific testing protocols and performance criteria to be used to verify accuracy of the submeters before they can be used in subtractive billing.
2. Until such time as the reliability of the submeters has been demonstrated, the performance verification standard should include the requirement for testing a statistically valid sample of newly manufactured submeters.

In this way, both the accuracy and reliability of the submeters can be guaranteed for use in submetering. Unfortunately, as experience with the usage data supplied during the pilot has shown, the submeter is only one of a number of components that are being used to deliver what is better thought of as a submetering *service* by the MDMAs.

The other components include: the customers' Wi-Fi that connects to the internet, the backhaul systems used by MDMA's to recover usage data from the submeters, and the data management systems used to format and transfer data from the MDMAs to the utilities. These system components have the potential to introduce large errors into the data.

Therefore, we recommend development of a more specific<sup>15</sup> submetering performance management standard. This standard should include:

- Minimum operating requirements to ensure that usage data is not lost due to communications system failures.
- The time interval for which submeter data must be delivered for each customer (e.g., daily, weekly, on a billing cycle, etc.).
- A standard protocol for validating, editing, and estimating submeter data that ensures the data that is delivered is properly formatted and accurate.
- Specifications for the format of the validated, edited, and estimated data that can be applied universally across all MDMAs and be accepted by all utilities that the CPUC regulates.

If utilities are required to accept submetering measurements from third parties, they will have to make investments to customize their data management systems to accommodate this new information. Standardizing the submetering data delivery structure may help with cost minimization of system design and implementation. However, utilities that have already made investments in automating the handling of incoming submeter data may incur significant costs to

revise their systems if the standards differ significantly from those already embedded in their systems.<sup>116</sup> Nevertheless, we believe the improvement in reliability of the submetering data will outweigh these costs in the long run.

One approach to develop such a standard could be for the California utilities<sup>117</sup> and submeter suppliers to jointly develop a California standard for measuring and delivering submeter data. This would help ensure that the interests of California utilities and submeter suppliers are directly addressed in the development process.

Another approach would be to wait for organizations that promulgate industrial performance standards to take up the problem (e.g., IEEE, ANSI, and ASTM). The advantage of having these third-parties develop the standard is that they are highly qualified to address all aspects of the problem, and are not overly influenced by business considerations of the various stakeholders. The drawback to this approach is that it can take years for standards committees to do their work while the need for submetering to support PEV submetering and other DER applications is here now and continues to grow.

The CPUC has taken the position that the pilot should not prematurely establish standards for submetering that might be inconsistent with emerging national standards.<sup>118</sup> That is certainly wise policy in the abstract. However, the absence of a coherent standard at this point—California or National—is preventing the development of a submetering services market. Nexant strongly recommends that the CPUC reconsider its position on this matter and instruct utilities in California to develop and adopt submetering standards that can be used to move the market forward in California.

From the start of discussions on submetering in 2011, the focus has been on supporting and promoting third-party MDMAs to develop and market submetering technology. Utilities have been prevented from offering submetering services. As both Phase 1 and Phase 2 of this pilot have shown, there continue to be technical challenges with submeter accuracy and reliable delivery of submeter data to the utilities. One way to overcome these problems is to allow utilities to offer submetering services in cooperation or competition with MDMAs. This would open up the possibility for greater customer choice via competition between the utilities and MDMAs, and promote opportunities for them to partner in the delivery of such services.

A further advantage of this strategy is that it can make use of recent advances in submetering technology as defined in [EPIC report 1.14](#)<sup>119</sup> that provide the ability to leverage the existing (utility owned) AMI mesh networks for submetering purposes. This technology is at the end of the development stage and will be deployed for PEV charging stations and telecommunication cell sites in 2019. Using existing utility operated wireless infrastructure may provide a much more reliable communications backbone to support the delivery of submetering information than will ever be possible with customer Wi-Fi over broadband internet.

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<sup>116</sup> SDG&E stated a standard that differed from their current data structure would result in increased costs.

<sup>117</sup> Utilities regulated by the CPUC.

<sup>118</sup> Decision 13-11-002, page 46, Finding of Fact 7. Stated: “The submetering pilot should be structured to support collaboration between parties, avoid prematurely setting a ‘California standard’ that is inconsistent with national efforts, and should be open to new and emerging business models in the evolving PEV market.”

<sup>119</sup> [https://www.pge.com/pge\\_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/EPIC-1.14.pdf](https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/EPIC-1.14.pdf)

The demand for submetering to support the adoption of PEVs and other DERs is here today and growing. CPUC has wisely supported the development of submetering technology and the market for submetering services in their nascent stages. Nexant respectfully recommends the continuation of that support by providing guidance to utilities and technology suppliers consistent with our recommendations as set forth above.

# Appendix A Question Bank and Guide for MDMA/Utility Interviews

## A.1 Utility Interviews

### *Administration Costs*

- What is your estimation of potential changes in costs per customer, at scale, that could be achieved through billing automation?
  - At a minimum, what processes would be automated vs. those that would remain manual?

### *Business Model*

- What is the total number of Submeter MDMAs and PEVs operating behind the primary utility meter?
  - How many distinct Submeter MDMA business models has the utility had experience with during the course of the pilot?

### *Business Process*

- Describe the process flows regarding all submeter transactions between the PEV, Submeter MDMA, and the utility, including:
  - Enrollment
  - File transfer
  - Data quality management
  - Billing
  - Resolution of customer inquiries

### *Service and Technology Innovations*

- What are the lessons learned from the PEV Submetering Pilot that can be applied to future submetering programs?

### *Issue Resolution*

- Describe the utility's ability and success rate to resolve customer issues.

### *Utility Disconnection*

- Describe the utility's ability to disconnect electric service at the primary meter for a customer receiving submetering service or to otherwise minimize the impact to third parties.

### *Technology Standardization*

- What are the opportunities for creating national standards related to MDMA-provided submetering technologies?
- What are the opportunities for implementing national standards for analysis of meter and billing data?

## **A.2 MDMA Interview Questions**

### **Administration Costs**

- What is your estimation of potential changes in costs per customer, at scale, that could be achieved through billing automation?
  - At a minimum, what processes would be automated vs. those that would remain manual?

### **Business Model**

- What is the total number of Submeter MDMAs and PEVs operating behind the primary utility meter?
  - How many distinct Submeter MDMA business models has the utility had experience with during the course of the pilot?

### **Business Process**

- Describe the process flows regarding all submeter transactions between the PEV, Submeter MDMA, and the utility, including:
  - Enrollment
  - File transfer
  - Data quality management
  - Billing
  - Resolution of customer inquiries

### **Service and Technology Innovations**

- What are the lessons learned from the PEV Submetering Pilot that can be applied to future submetering programs?

### **Issue Resolution**

- Describe the utility's ability and success rate to resolve customer issues.

### **Utility Disconnection**

- Describe the utility's ability to disconnect electric service at the primary meter for a customer receiving submetering service or to otherwise minimize the impact to third parties.

### **Technology Standardization**

- What are the opportunities for creating national standards related to MDMA-provided submetering technologies?
- What are the opportunities for implementing national standards for analysis of meter and billing data?

## Appendix B Participant Survey Instruments

### B.1 Welcome Survey

#### PEV Submetering Phase 2 Customer Experience Survey

[INCLUDES NEXANT AND CPUC LOGOS ON LANDING PAGE]

Welcome! Thank you for participating in this Submetering Pilot of a new electric metering option that allows your utility to bill you at a special rate for the electricity used by your plug-in electric vehicle (PEV). This short survey is designed to collect information about your experiences to date. Your answers will help improve how submetering may be offered to PEV owners in California.

Remember that responses are confidential and will only be reported in aggregate.

This survey will take about 10 minutes.

#### *About your plug-in electric vehicle (PEV)*

[TRANSITION SCREEN]

First, we have some questions about your PEV(s) and about your charging habits.

Q1. [OPEN ENDED: SHORT]

1. How many PEVs do you own? \_\_\_\_\_

Q2. [OPEN ENDED: SHORT]

2. Please list the make, model and year of your PEV(s) (number of rows to fill in is equal to the answer provided in Q1):

Make	Model	Year	Month and year of lease/purchase	Miles driven in a typical weekday (M-F)

Q3. [MULTI CHOICE: one selection per column and up to three rows. Move question to after Q5]

3. Please describe how often you typically charge your PEV away from home (drop downs, customers can fill in up to three rows):

Days per week	Charger Type	Avg. Duration
0 days		
1 day		Less than 1 hour
2 days	DC Fast Charging	Between 1 and 2 hours
3 days	Level 2 Charging	Between 2 and 3 hours
4 days	Level 1 Charging	Between 3 and 4 hours
5 days		More than 4 hours
6 days	Not sure	Not sure
7 days		
Not sure		

**Q4. [MULTI CHOICE: one selection per row]**

4. When did you normally charge your PEV at home...

**[ROWS]**

r1. ...before participating in the submetering pilot?

r2. ...during the submetering pilot?

**[COLUMNS]**

c1. Any time

c2. Weekday nights and early mornings from **[if Utility=**

1. 11pm to 7am

2. 9pm to 7am

3. midnight to 5am

**]**

c3. Weekday afternoons and evenings from **[if Utility=**

1. 2pm to 9pm

2. noon to 9pm

3. noon to 6pm

**]**

c4. Other times on weekdays

c5. Weekends

**[Utility Mapping: PG&E = 1; SCE = 2; SDG&E = 3]**

**Q5. [SINGLE CHOICE]**

5. Do you use a timer to control when your PEV charges?

1. Yes, always

2. Yes, most of the time

3. Yes, but not very often

4. No, never

**About Your Submetering Service****[TRANSITION]**

Next, we have a few questions about your experience with submetering.

**Q6. [SINGLE CHOICE]**

6. Did you participate in Phase 1 of the submetering pilot?

1. Yes
2. No

**Q7. [MULTI CHOICE: check all that apply]**

7. How did you learn about the PEV submetering pilot? (Check all that apply)

1. Contacted by (insert MDMA name)
2. (insert utility name) website
3. Auto dealer
4. PEV rebate website
5. Internet search. What terminologies or topics did you search for? \_\_\_\_\_
6. A neighbor or friend
7. Electric Vehicle Group
8. Internet marketing / advertisement
9. California Public Utilities Commission (CPUC) website
10. Participation in Phase 1 **[show option only if Q6 = 1]**
11. Other. Please explain. \_\_\_\_\_

**Q8. [SINGLE CHOICE: ASK ONLY IF Q7 = 1]**

8. Which vendor did you use in Phase 1?

1. eMotorWerks / OhmConnect
2. NRG

**Q9. [SINGLE CHOICE: ASK ONLY IF Q7 = 1]**

9. How would you rate your experience in Phase 2 relative to Phase 1?

1. Much better
2. Somewhat better
3. No change
4. Somewhat worse
5. Much worse

**Q10. [OPEN ENDED: LONG. Ask ONLY if Q9 is NOT EQUAL to 3 (“No change”)]**

10. Please describe what is different about your experience in Phase 2.

**Q11. [MULTI CHOICE: one selection per row]**

11. How important was each of the following aspects of submetering in deciding to sign up for the pilot?

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all
1. Ability to charge my vehicle more quickly				
2. The cost of the vehicle charger (including incentives)				
3. Ability to pay a lower rate for electricity used by my PEV				
4. The ability to control the charging station from my smartphone				
5. The safety and reliability of the charging station				
6. Ability to measure the amount of electricity my vehicle is using				
7. The availability of an incentive for the PEV submeter				
8. Other (please insert)				

**Q12. [MULTI CHOICE: one selection per row]**

12. Which of the following best describes the price structure of electricity you now use specifically:

**[COLUMNS]**

c1. ...for your PEV?

c2. ...for the rest of your home?

**[ROWS]**

r1. Same price for all hours of the day

r2. More expensive during peak period and less expensive during off-peak period

**Q13. [SINGLE CHOICE]**

13. When you enrolled in the PEV submetering pilot, were you aware that a time-of-use (TOU) rate for your whole house (including your PEV) was available to you from (Insert utility Name)?

1. Yes
2. No
3. Not sure

**Q14. [MULTI CHOICE: Check all that apply, ask only if Q13 = 1]**

14. Why did you choose submetering over a rate that applies to your whole house? (Check all that apply)

1. My bills are lower with submetering
2. Submetering was recommended to me by \_\_\_\_\_
3. I received an incentive for the PEV submeter
4. Other. Please explain: \_\_\_\_\_

**Q15. [SINGLE CHOICE]**

15. Have you accessed any data collected by your submeter during the pilot?

1. Yes
2. No
3. Not sure

**Q16. [MULTI CHOICE: Check all that apply, ask only if Q15 = 1]**

16. What type of data did you access?

1. Electricity usage
2. Cost
3. Emissions
4. Other. Please explain. \_\_\_\_\_

Q17. **[MULTI CHOICE: Check all that apply, ask only if Q15 = 1]**

17. What tools or technologies did you use to access the data?

1. Website
2. Smartphone app
3. On-board vehicle display
4. Other. Please explain. \_\_\_\_\_

**Phase 2 Pilot experience**

Q18. **[SINGLE CHOICE]**

18. How would you rate your overall satisfaction with your submetering service?

1. Extremely satisfied
2. Somewhat satisfied
3. Neither satisfied nor dissatisfied
4. Somewhat dissatisfied
5. Extremely dissatisfied

Q19. **[MULTI CHOICE: One selection per row. Randomize rows 1-8. Ask only if Q18 = 4 (“Somewhat dissatisfied”) or 5 (“Extremely dissatisfied”)]**

19. How important was each of the following aspects in contributing to your dissatisfaction?

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all	Did not experience
1. Errors resulting from submeter accuracy during the pilot period					
2. Not enough bill savings					
3. Late or inaccurate bills					
4. [Insert MDMA name] customer service					
5. [Insert utility name] customer service					
6. Difficulty with the registration process					
7. Terms of submetering pilot participation defined by [utility]					

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all	Did not experience
8. Terms of submetering contract with [MDMA]					
9. Other technical problems (please explain)					
10. Other billing problems (please explain)					
11. Other problems (please explain)					

Q20. **[MULTI CHOICE: Check all that apply. Randomize rows 1-8. Ask only if Q18 = 1 (“Extremely satisfied”) or 2 (“Somewhat satisfied”)]**

20. How important was each of the following aspects in contributing to your satisfaction?

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all
1. Satisfaction with the overall program				
2. The ability to pay a special rate and reduce your electricity bill				
3. The ability to track your PEV usage separately from your household usage				
4. Submetering was easy to set up				
5. Receiving a discount on a Level 2 PEV charging station				
6. Avoiding the cost of installing a separate utility meter				
7. Accuracy of PEV charging usage measured by the submeter				
8. Terms of				

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all
submetering pilot participation defined by [utility]				
9. Terms of submetering contract with [MDMA]				
10. Other (please explain)				

Q21. **[SINGLE CHOICE: Ask ONLY if Q19 rows 1 AND 9 not = 5 “Did not experience”.]**

21. How satisfied were you with the resolution of the technical problem(s)?

1. Extremely satisfied
2. Somewhat satisfied
3. Neither satisfied nor dissatisfied
4. Somewhat dissatisfied
5. Extremely dissatisfied
6. The problem(s) is/are still unresolved

Q22. **[SINGLE CHOICE: Ask ONLY if Q19 rows 3 AND 10 not = 5 “Did not experience”.]**

22. How satisfied were you with the resolution of the billing problem(s)?

1. Extremely Satisfied
2. Somewhat satisfied
3. Neither satisfied nor dissatisfied
4. Somewhat dissatisfied
5. Extremely dissatisfied
6. The problem(s) is/are still unresolved

Q23. **[MULTI CHOICE: One selection per row. Do not randomize rows]**

23. Please rate the following aspects of your submetering service during the pilot.

	Excellent	Very good	Good	Fair	Poor	Did not experience
1. Scheduling the installation of the meter or charging station						
2. The installation appointment						
3. Signing up for the PEV rate with (insert utility name)						

	Excellent	Very good	Good	Fair	Poor	Did not experience
4. Accuracy of PEV portion of your bill						
5. Customer service provided by (insert utility name) after PEV rate started						
6. Customer service provided by (insert MDMA name) after the meter or charging station was installed						
7. Safety of my charging station						
8. Accuracy of the measurement of electricity used by my PEV						
9. Reliability of my charging station						
10. Ability to control my charging station remotely						
11. Access to information about whether and when my vehicle is charging remotely						
12. Utility bill savings resulting from the special PEV rate						

Q24. **[OPEN ENDED: LONG]**

24. What improvements would you like to see in your submetering service?

**Q25. [SINGLE CHOICE]**

25. Would you participate in another pilot related to PEVs?

1. Yes
2. No
3. Not sure

**Demographics****[TRANSITION]**

Finally, we will ask a few questions about your household. Please remember that your answers will be kept confidential.

**Q26. [SINGLE CHOICE]**

26. Please select your gender.

1. Female
2. Male
3. Other

**Q27. [SINGLE CHOICE]**

27. Please select your marital status.

1. Single
2. Married
3. Divorced
4. Widowed
5. Other

**Q28. [SINGLE CHOICE]**

28. Please select your age bracket.

1. 18 to 24
2. 25 to 34
3. 35 to 44
4. 45 to 54
5. 55 to 64
6. 65 to 74
7. 75 or over

**Q29. [SINGLE CHOICE]**

29. Do you own or rent your residence?

1. Own
2. Rent
3. Other

**Q30. [SINGLE CHOICE]**

30. Which of the following best describes your place of residence? (Programmer: radio buttons select one answer only)

1. A single family house detached from any other house
2. A residential building with 2 to 4 apartments or condominiums
3. A residential building with 5 to 10 apartments or condominiums
4. A building with more than 10 apartments or condominiums
5. A mobile or manufactured home

**Q31. [SINGLE CHOICE]**

31. What is your approximate annual household income before taxes?

1. Less than \$50,000
2. \$50,000-100,000
3. \$100,000-175,000
4. \$175,000-250,000
5. Greater than \$250,000

**Q32. [SINGLE CHOICE]**

32. What is the highest grade of schooling anyone in your household has completed?

1. High school diploma or less
2. Some college or trade school
3. Two year degree
4. Four year degree
5. Graduate degree or higher

***End of Survey Recruitment for logger installations and collection of address for thank you check:***

**Proposed Wording:**

**Q33.** There may be additional opportunity for you to participate in a \$150 paid study. If such an opportunity were to become available, a Nexant representative will contact you to schedule an appointment so that an engineer can visit your home to install a data logging device near your submeter. The appointment will take about 45 minutes and you will receive a \$100 check. About two months later, the engineer will return to retrieve the device. At that time, you will receive a \$50 check. The second appointment usually takes less than 45 minutes.

33. If such an opportunity were to become available, would you like a Nexant staff member to contact you?

1. Yes, OK to contact me. Name: \_\_\_\_\_ Phone: \_\_\_\_\_
2. No thanks, I'm not interested

**Q34.** Thank you for completing the survey.

34. Please let us know the address to which you would like Nexant to mail your \$25 thank you check (allow 2-4 weeks for processing).

1. Name: \_\_\_\_\_
2. Street address: \_\_\_\_\_
3. City: \_\_\_\_\_
4. Zip code: \_\_\_\_\_

**[FINAL SCREEN]**

You've reached the end of the survey. Thank you for your participation!

**[CLICK ON BUTTON AND REDIRECT TO THE CPUC'S PILOT WEBPAGE:**

**<http://www.cpuc.ca.gov/general.aspx?id=5938/>**

## B.2 Unenrolled, Incomplete, and Prospective Survey

### PEV Submetering Phase 2 Unenrolled Customer Survey

[INCLUDES NEXANT AND CPUC LOGOS ON LANDING PAGE]

[NOTE THAT SURVEY LOGIC THROUGHOUT IS BASED ON PARTICIPANT STATUS: PROSPECT (those who never submitted a CEA), INCOMPLETE (those who did not complete the enrollment process), UNENROLLED (those who enrolled but later exited the pilot). INVITE LIST WILL ALSO INCLUDE A “WELCOME” COLUMN THAT WILL EQUAL 1 if a WELCOME SURVEY WAS COMPLETED.]

Welcome! We understand that you [UN-ENROLLED: “un-enrolled from the Submetering pilot early”, PROSPECT: “did not start the Submetering pilot enrollment process”, INCOMPLETE: “did not complete the Submetering pilot enrollment process”]. This short survey is designed to collect information about [UN-ENROLLED: “your experiences with the Submetering pilot to date”, PROSPECT AND INCOMPLETE: “your interest in Submetering pilot and reasons for not enrolling”]. Your answers will help inform how and if submetering may be offered to PEV owners in California. To thank you for your time, Nexant will mail you a \$25 check if you [PROSPECT: qualify for and] complete the survey.

Remember that responses are confidential and will only be reported in aggregate.

This survey will take about 10 minutes.

#### Phase 2 Pilot / Enrollment Experience

[TRANSITION SCREEN]

First, we have a few questions about your [UNENROLLED: “experience with”, PROSPECT AND INCOMPLETE: “*interest in*”] submetering.

Q35. [SINGLE CHOICE. ASK ONLY IF PROSPECT]

35. Did you enroll in Phase 2 of the PEV Submetering pilot?
1. Yes
  2. No

[FINAL SCREEN: SHOW ONLY IF Q35= 1 AND PROSPECT]

We are looking for respondents who fit a different profile. Thank you for your time.

Q36. [SINGLE CHOICE. ASK ONLY IF UNENROLLED]

36. How would you rate your overall satisfaction with your submetering service?
1. Extremely satisfied
  2. Somewhat satisfied
  3. Neither satisfied nor dissatisfied
  4. Somewhat dissatisfied
  5. Extremely dissatisfied

**Q37. [MULTI CHOICE: one selection per row SKIP IF WELCOME SURVEY]**

37. How important was each of the following aspects of submetering in **[IF NO WELCOME SURVEY AND UNENROLLED: “deciding to sign up for the pilot?” IF PROSPECT OR INCOMPLETE considering whether to sign up for the pilot?”]**

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all
1. Ability to charge my vehicle more quickly				
2. The cost of the vehicle charger / charging station (including incentives)				
3. Ability to pay a lower rate for electricity used by my PEV				
4. The ability to control the charging station from my smartphone				
5. The safety and reliability of the charging station				
6. Ability to measure the amount of electricity my vehicle is using				
7. The availability of an incentive for the PEV submeter				
8. Other (please explain)				

**Q38. [SINGLE CHOICE: one selection per row; DO NOT SHOW TO PROSPECTS]**

38. How would you rate your overall satisfaction with your submetering enrollment process?

r1. [Utility]

r2. [MDMA]

c1. Extremely satisfied

c2. Somewhat satisfied

c3. Neither satisfied nor dissatisfied

c4. Somewhat dissatisfied

c5. Extremely dissatisfied

Q39. **[MULTI CHOICE: one selection per row; ASK ONLY IF INCOMPLETE OR PROSPECT]**

39. How important was each of the following aspects of submetering in your not **[INCOMPLETE: “completing”, PROSPECT: “starting”]** the enrollment process for the pilot?

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all
1. The enrollment process was complicated				
2. I didn't think I would save enough with the rate offered				
3. I didn't want to limit my charging on weekday afternoons / evenings				
4. I didn't think the rate was compatible with my net metered PV solar production				
5. I would have wanted to stay on the rate for more than 12 months				
6. I didn't want to or couldn't un-enroll from other programs (auto-pay, demand response, etc.)				

7. I didn't qualify for the pilot for another reason (please explain)				
8. I don't usually charge my car at home				
9. Other (please explain)				

**Q40. [OPEN ENDED: LONG ASK ONLY IF PROSPECT OR INCOMPLETE]**

40. What improvements would you like to see in the submetering enrollment **[INCOMPLETE: "process you experienced", PROSPECT: "requirements"]**? Are there additional details you would like to include about your reasons for **[INCOMPLETE: "not completing the enrollment process, PROSPECT: "not enrolling"]**?

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**Q41. [MULTI CHOICE: One selection per row. Randomize rows 1-6. ASK ONLY IF UNENROLLED]**

41. How important was each of the following aspects in contributing to your un-enrollment from the pilot?

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all	Did not experience
1. Errors resulting from submeter accuracy during the pilot period					
2. Not enough bill savings					
3. Late or inaccurate bills					
4. [Insert MDMA name] customer service					
5. [Insert utility name] customer service					

6. I no longer have an EV					
7. Other technical problems (please explain)					
8. Other billing problems (please explain)					
9. Other problems (please explain)					

**Q42. [OPEN ENDED: LONG. ASK ONLY IF UNENROLLED]**

42. What improvements would you like to see in the submetering service you experienced?  
Are there additional details you would like to include about your reasons for un-enrolling?

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**Q43. [SINGLE CHOICE]**

43. Would you participate in another pilot related to PEVs?

1. Yes
2. No

**About Your Plug-In Electric Vehicle (PEV)**

**[TRANSITION SCREEN: SHOW ONLY IF NO WELCOME RESPONSE]**

**Next, we have some questions about your PEV(s) and about your charging habits.**

**Q44. [OPEN ENDED: SHORT]**

44. How many PEVs do you own? \_\_\_\_\_

**Q45. [OPEN ENDED: SHORT ; ASK ONLY IF NO WELCOME RESPONSE, SKIP IF Q1 = 0]**

45. Please list the make, model and year of your PEV(s) (number of rows to fill in is equal to the answer provided in Q1):

Make	Model	Year

Q46. **[MULTI CHOICE: one selection per row ; ASK ONLY IF NO WELCOME RESPONSE AND UNENROLLED, SKIP IF Q9 = 0]**

46. When did you normally charge your PEV at home...

**[ROWS]**

- r1. ...before participating in the submetering pilot?
- r2. ...during the submetering pilot?
- r3. ...after the submetering pilot?

**[COLUMNS]**

- c1. Any time
- c2. Weekday nights and early mornings from **[if Utility=**
  - 1. 11pm to 7am
  - 2. 9pm to 7am
  - 3. midnight to 5am
- ]**
- c3. Weekday afternoons and evenings from **[if Utility=**
  - 1. 2pm to 9pm
  - 2. noon to 9pm
  - 3. noon to 6pm
- ]**
- c4. Other times on weekdays
- c5. Weekends

**[Utility Mapping: PG&E = 1; SCE = 2; SDG&E = 3]**

Q47. **[SINGLE CHOICE: ASK ONLY IF PROSPECT]**

47. Who is your electricity provider?

- 1. PG&E
- 2. SCE
- 3. SDG&E
- 4. Other (please specify)
- 5. I don't know

Q48. **[MULTI CHOICE: one selection per row ; ASK ONLY IF PROSPECT OR INCOMPLETE, SKIP IF Q9 = 0]**

48. When do you normally charge your PEV at home?

- 1. Any time
- 2. Weekday nights and early mornings
  - 1. from 11pm to 7am **[if Q47 = 1]**
  - 2. from 9pm to 7am **[if Q47 = 2]**
  - 3. from midnight to 5am **[if Q47 = 3]**
  - 4. [blank if **Q47 = 4 or 5**, e.g. response 2 should just read “Weekdays nights and early mornings” but not specify a time range]
- 3. Weekday afternoons and evenings
  - 1. from 2pm to 9pm **[if Q47 = 1]**
  - 2. from noon to 9pm **[if Q47 = 2]**
  - 3. from noon to 6pm **[if Q47 = 3]**

4. [blank if Q47 = 4 or 5, e.g. response 3 should just read “Weekday afternoons and evenings” but not specify a time range]

- 4. Other times on weekdays
- 5. Weekends

**[Utility Mapping: PG&E = 1; SCE = 2; SDG&E = 3]**

**Q49. [SINGLE CHOICE: ASK ONLY IF NO WELCOME RESPONSE, SKIP IF Q9 = 0]**

49. Do you use a timer to control when your PEV charges?

- 1. Yes, always
- 2. Yes, most of the time
- 3. Yes, but not very often
- 4. No, never

**Q50. [MULTI CHOICE: one selection per row]**

50. Which of the following best describes the price structure of electricity you now use?

- 1. Same price for all hours of the day
- 2. More expensive during peak period and less expensive during off-peak period

## Demographics

### [TRANSITION]

Finally, we will ask a few questions about your household. Please remember that your answers will be kept confidential.

**Q51. [SINGLE CHOICE]**

51. Please select your gender.

- 1. Female
- 2. Male
- 3. Other

**Q52. [SINGLE CHOICE]**

52. Please select your marital status.

- 1. Single
- 2. Married
- 3. Divorced
- 4. Widowed
- 5. Other

**Q53. [SINGLE CHOICE]**

53. Please select your age bracket.

- 1. 18 to 24
- 2. 25 to 34

3. 35 to 44
4. 45 to 54
5. 55 to 64
6. 65 to 74
7. 75 or over

**Q54. [SINGLE CHOICE]**

54. Do you own or rent your residence?

1. Own
2. Rent
3. Other

**Q55. [SINGLE CHOICE]**

55. Which of the following best describes your place of residence? (Programmer: radio buttons select one answer only)

1. A single family house detached from any other house
2. A residential building with 2 to 4 apartments or condominiums
3. A residential building with 5 to 10 apartments or condominiums
4. A building with more than 10 apartments or condominiums
5. A mobile or manufactured home

**Q56. [SINGLE CHOICE]**

56. What is your approximate annual household income before taxes?

1. Less than \$50,000
2. \$50,000-100,000
3. \$100,000-175,000
4. \$175,000-250,000
5. Greater than \$250,000

**Q57. [SINGLE CHOICE]**

57. What is the highest grade of schooling anyone in your household has completed?

1. High school diploma or less
2. Some college or trade school
3. Two year degree
4. Four year degree
5. Graduate degree or higher

**End of Survey collection of address for thank you check:**

**Q58.** Thank you for completing the survey.

58. Please let us know the address to which you would like Nexant to mail your \$25 thank you check (allow 2-4 weeks for processing).

1. Name: \_\_\_\_\_
2. Street address: \_\_\_\_\_
3. City: \_\_\_\_\_
4. Zip code: \_\_\_\_\_

**[FINAL SCREEN]**

You've reached the end of the survey. Thank you for your participation!

**[CLICK ON BUTTON AND REDIRECT TO THE CPUC'S PILOT WEBPAGE:**

**<http://www.cpuc.ca.gov/general.aspx?id=5938>**]

### B.3 Post Pilot Survey

#### PEV Submetering Pilot Post Phase 2 Survey

Imported Variables:

- MDMA: name of participant's MDMA
- Utility: name of participant's utility
- InfoAccessType[1,2,3]: each equals 0 or 1
- DissatisfactionReason equals 0, 1, 2, 3, 4, 5, 6, 7 or 8
- PoorAspects[1,2,3,4,5,6]; each equals 0 or 1

Welcome! During the last year you participated in a pilot test of a new electric metering option that allowed your utility to bill you at a special lower plug-in electric vehicle (PEV) rate for the electricity used by your PEV. This short survey is designed to collect information about your experiences during the pilot. Your answers will help improve how submetering is offered to PEV owners in California if authorized by the California Public utilities Commission (CPUC). We sincerely appreciate your time.

This is a follow up to the survey you took towards the beginning of the pilot. We may reference some responses you gave in that initial survey, referred to here as the "welcome survey".

This survey will take about 8 minutes.

#### **INTRODUCTION: PARTICIPATION IN PILOT**

##### **[TRANSITION SCREEN]**

First, we have some questions about your participation in the submetering pilot.

Q1. **[MULTI-QUESTION]**

When was the most recent month in which you participated in the pilot?

1. Month: **[drop down with month names]**
2. Year: **[drop down with: 2017, 2018]**

Q2. **[OPEN ENDED: SHORT]**

When you began the submetering pilot you owned at least one plug-in electric vehicle (PEV). How many PEVs do you currently own now?

\_\_\_\_\_

Q3. **[SINGLE CHOICE]**

Considering your experience in the pilot, would you recommend submetering service to a friend or colleague?

1. Yes
2. No
3. Not sure

**Q4. [SINGLE CHOICE]**

Is a program with roughly the same pricing and features as those offered in this pilot an important service for the utility to be offering to customers?

1. Extremely important
2. Somewhat important
3. Neither important nor unimportant
4. Somewhat unimportant
5. Extremely unimportant

**Q5. [SINGLE CHOICE]**

If this were to become a program with roughly the same pricing and features, how likely would you be to participate in the future?

1. Extremely likely
2. Somewhat likely
3. Neither likely nor unlikely
4. Somewhat unlikely
5. Extremely unlikely

**Q6. [SINGLE CHOICE: ASK ONLY IF Q5=4 OR 5]**

What is the primary reason you would be unlikely to participate in a program with roughly the same pricing and features in the future?

1. errors resulting from submeter accuracy
2. not enough bill savings
3. late or inaccurate bills
4. **[MDMA]** customer service
5. **[Utility]** customer service
6. difficulty of the registration process
7. Other. Please explain

**Q7. [OPEN ENDED: LONG. ASK ONLY IF Q6 WAS ASKED]**

1. submeter accuracy
2. bill savings
3. timeliness and accuracy of bills
4. **[MDMA]** customer service
5. **[Utility]** customer service
6. the registration process
7. your submetering service]

Please explain in what way **[pipe in numbered item above corresponding to Q6 response]** did not meet your expectations and how the submetering program could be improved to address this.

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Q8. **[GRID: One choice per row.]**

Your ability to pay a lower rate for electricity used by your PEV depends on several processes to calculate your bill. Who do you think is responsible for ensuring that each of the following aspects is completed accurately and timely?

**[ROWS]**

- r1. Measurement of the electricity used by your vehicle
- r2. Ensuring measurements of the electricity used by your vehicle are accurate
- r3. Resolving errors in the measurement of electricity used by your EV
- r4. Addressing technical problems with the submeter
- r5. Ensuring your bills are accurate
- r6. Ensuring your bills are timely

**[COLUMNS]**

- c1. **[Utility]**
- c2. **[MDMA]**
- c3. Both

Q9. **[SINGLE CHOICE]**

Considering your experience in the pilot, which of the following arrangements would be the best arrangement for a program with roughly the same pricing and features in the future?

- 1. An arrangement similar to the one in the current pilot in which **[MDMA]** installs and maintains the meter and **[Utility]** is responsible for calculating the bill and receiving payment.
- 2. An arrangement in which **[Utility]** is responsible for all aspects of the service.
- 3. Not sure

Q10. **[OPEN ENDED: LONG. Ask only if Q9= 1 OR 2]**

- 1. an arrangement similar to the one in the current pilot in which **[MDMA]** installs and maintains the meter and **[Utility]** is responsible for calculating the bill and receiving payment.
- 2. an arrangement in which **[Utility]** is responsible for all aspects of the service. ]

Please explain the benefits of **[pipe in numbered item above corresponding to Q9 response]**

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**BEHAVIOR AND PERCEPTIONS**

- Q11. **[MULTI CHOICE: one selection per row. Skip if NO InfoAccessType = 1]**  
In the welcome survey, you said you used the following tools or technologies to access data from your submeter.

How often would you say you viewed your submeter data in this way during the pilot?

**[ROWS: show only rows corresponding to InfoAccessType[1,2,3] = 1]**

- r1. Website
- r2. Smartphone app
- r3. On-board vehicle display

**[COLUMNS]**

- c1. Never
- c2. Once or twice
- c3. Sometimes (1 to 2 times per month)
- c4. Several times per month
- c5. Very frequently (multiple times per week)

- Q12. **[SINGLE CHOICE]**  
Do you feel that you saved money due to participating in this submetering pilot?

- 1. Yes
- 2. No
- 3. Not sure

- Q13. **[OPEN ENDED: SHORT]**  
About how much would you say you typically spent each month charging your PEV during the submetering pilot?

\$\_\_\_\_\_

☐ Don't know

- Q14. **[OPEN ENDED: SHORT]**  
You said you spent about [Q13] each month charging your PEV during the submetering pilot. About how much do you think you would have spent each month without submetering?

\$\_\_\_\_\_

**Q15. [MULTI CHOICE: one selection per row]**

When did you normally charge your PEV...

**[ROWS]**

- r1. ...before participating in the submetering pilot?
- r2. ...during the submetering pilot?
- r3. ...after the submetering pilot?

**[COLUMNS]**

- c1. Any time
- c2. Weekday nights and early mornings from **[if Utility=**
  - 1. 11pm to 7am
  - 2. 9pm to 7am
  - 3. midnight to 5am**]**
- c3. Weekday afternoons and evenings from **[if Utility=**
  - 1. 2pm to 9pm
  - 2. noon to 9pm
  - 3. noon to 6pm**]**
- c4. Other times on weekdays
- c5. Weekends

**PAIN POINTS****[TRANSITION]**

Next, we have a few questions about your experience with submetering.

**Q16. [SINGLE CHOICE]**

Now that you have received submetering service for the duration of your participation in the pilot, how would you rate your overall satisfaction with your submetering service?

- 1. Extremely satisfied
- 2. Somewhat satisfied
- 3. Neither satisfied nor dissatisfied
- 4. Somewhat dissatisfied
- 5. Extremely dissatisfied

**Q17. [RANK ORDER. Ask only if Q16= 1 OR 2. Drag and drop to rank. Randomize Choices]**

Please rank the following reasons in order of importance to your overall satisfaction with your submetering service (1 being the most important).

*To rank the listed items drag and drop each item.*

- Ability to pay a lower rate and reduce your electricity bill
- Ability to track your PEV usage separately from your household usage
- Submetering was easy to set up
- Avoiding the cost of installing a second meter
- Other. Please explain: \_\_\_\_\_

**Q18. [RANK ORDER. Ask only if Q16 = 4 OR 5. Drag and drop to rank. Randomize Choices]**

Please rank the following reasons in order of importance to your overall dissatisfaction with your submetering service (1 being the most important reason for your dissatisfaction).

*To rank the listed items drag and drop each item.*

- Billing accuracy
- Lateness of bills
- Customer service or support from **[Utility]**
- Customer service or support from **[MDMA]**
- Usability of charging device
- Other. Please explain: \_\_\_\_\_

**Q19. [OPEN ENDED: LONG. Ask only if Q16 = 4 OR 5]**

Consider your dissatisfaction with **[Q18 Rank 1 response label, if Q18 Rank 1 = "Other", pipe in "your submetering service"]**.

What do you think should be done to improve the program in the future?

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Q20. **[OPEN ENDED: LONG.**

**Skip if:**

**DissatisfactionReason = 0**

**OR**

**DissatisfactionReason = 3 AND Q18 Rank 1 response = Billing accuracy**

**OR**

**DissatisfactionReason = 3 AND Q18 Rank 1 response = Lateness of bills**

**OR**

**DissatisfactionReason = 4 AND Q18 Rank 1 response = Customer service or support from [MDMA]**

**OR**

**DissatisfactionReason = 5 AND Q18 Rank 1 response = Customer service or support from [Utility]**

**Pipe in reason below based on DissatisfactionReason value as follows:**

1. errors resulting from submeter accuracy
2. not enough bill savings
3. late or inaccurate bills
4. customer service or support from [MDMA]
5. customer service or support from [Utility]
6. terms of submetering pilot participation defined by [Utility]
7. terms of submetering contract with [MDMA]
8. technical problems

**]**

In the welcome survey you stated you were dissatisfied with the submetering pilot due to **[pipe in DissatisfactionReason]**.

What do you think should be done about this in the future?

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Q21. **[GRID: One choice per row. Skip if NO Poor Aspects = 1]**

Below are some aspects of your submetering service you rated fair or poor in the welcome survey.

Please indicate whether you noticed a change in any aspect since the welcome survey.

**[ROWS: Show only items corresponding to Poor Aspects[1,2,3,4,5,6] = 1]**

- r1. Accuracy of the EV portion of your bill
- r2. Customer service provided by [Utility] after EV rate started
- r3. Customer service provided by [MDMA] after the meter or charging station was installed
- r4. Accuracy of the measurement of electricity used by my EV
- r5. Ability to control my charging station remotely
- r6. Access to information about whether and when my vehicle is charging remotely

**[COLUMNS]**

- c1. Improved
- c2. Did not change
- c3. Became worse

**Q22. [OPEN ENDED: LONG]**

Below are the aspects of your submetering service which did not improve. Please describe the improvement you would have liked to see for each aspect.

**[Show only items for which Q21 NOT = 1. If all in Q21=1 then SKIP. Show in table format with item description in narrow left hand column and wide response area in right hand column]**

**Q23. [OPEN ENDED: LONG]**

Please describe anything else you would like to share about your experience with submetering.

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**DEMOGRAPHICS****[TRANSITION]**

Finally, we will ask a few questions about your household. Please remember that your answers will be kept confidential.

**Q24. [SINGLE CHOICE]**

Please select your gender.

- 1. Female
- 2. Male
- 3. Other

**Q25. [SINGLE CHOICE]**

Please select your marital status.

1. Single
2. Married
3. Divorced
4. Widowed
5. Other

**Q26. [SINGLE CHOICE]**

Please select your age bracket.

1. 18 to 24
2. 25 to 34
3. 35 to 44
4. 45 to 54
5. 55 to 64
6. 65 to 74
7. 75 or over

**Q27. [SINGLE CHOICE]**

Do you own or rent your residence?

1. Own
2. Rent
3. Other

**Q28. [SINGLE CHOICE]**

What is your approximate annual household income before taxes?

1. Less than \$50,000
2. \$50,000-100,000
3. \$100,000-175,000
4. \$175,000-250,000
5. Greater than \$250,000

**Q29. [SINGLE CHOICE]**

What is the highest grade of schooling anyone in your household has completed?

1. High school diploma or less
2. Some college or trade school
3. Two year degree
4. Four year degree
5. Graduate degree or higher

## Appendix C Regulatory Compliance

### C.1 Compliance with Decision 13-11-002 as it Pertains to Evaluation

Decision 13-11-002 provided guidance on the scope of the evaluation. Resolution E-4651 and subsequent Tier 2 advice letters provide additional information pertaining to the requirements of the pilot program, but do not provide further details on the evaluation study. The decision states that the evaluation scope may include, but is not required to include, the nine evaluation categories below:

1. Comparison of the total cost of metering services.
2. Access to PEV tariffs.
3. Multiple Submeter MDMA's and PEVs operating behind a primary meter.
4. Utility disconnection capability.
5. Customer satisfaction.
6. Reliability of data, technology, and service.
7. Service and technology innovations.
8. Technology standardization.
9. Cost minimization.

The following sections of the evaluation address each of these topics, and identify whether Nexant ultimately included them in the evaluation, and if not, the justification for doing so. These sections either address the topic or refer the reader to the appropriate section of the report.

### C.2 Comparison of the total cost of metering services

The final decision defines the topic of “comparison of the total cost of metering services” as: “Metering, electrical equipment, and labor cost; installation time and processes; fixed energy and/or demand costs; and number and type of PEVs participating and miles driven. Compare total cost for submetering to a) separate PEV metering, and b) Submeter.”

During the interviews with the stakeholders, basic cost information was collected. Later, Nexant obtained more detailed estimates from the three utilities regarding estimated costs for the pilot study and the estimated costs at scale. However, these preliminary rate estimates were generated solely to provide cost approximations for use in this study and should not be considered robust and detailed enough for future rate proceedings. Please see Section 4.6 for the cost analysis of installing a separate utility-grade meter, installing a submeter at full scale with automation, and a comparison between the two scenarios.

### C.3 Access to PEV Tariffs

The decision defines the topic of “Access to PEV tariffs” as: “Total number of PEV-only rate or charging options available to customers enrolled in submetering.” To satisfy this request, we asked the utilities for information about their PEV-specific rates and also searched online. As of September, 2018, the utilities offer the following residential rates for PEVs.

**PG&E:**

- **EV-A:** non-tiered, whole-house TOU rate for PEVs. Rates vary from approximately \$0.12 / kWh off-peak (summer) to \$0.48 per kWh on-peak (summer).
- **EV-B:** non-tiered, TOU rate that requires installation of a second meter for the PEV. Rates vary from \$0.13 / kWh off-peak (summer) to \$0.47 / kWh on-peak with a daily meter charge of approximately \$0.049.<sup>120</sup>

**SCE:**

- **TOU-EV-1:** non-tiered rate, TOU that requires installation of a second meter for the PEV. This rate ranges from \$0.13 / kWh off-peak to \$0.37 / kWh on-peak and requires a monthly meter charge of \$2.76.<sup>121</sup>

**SDG&E:**

- **EV-TOU:** non-tiered rate, TOU rate that requires installation of a second meter for the PEV. Rates vary from \$0.23 / kWh off-peak to \$0.54 / kWh on-peak.
- **EV-TOU-2:** non-tiered, TOU rate that uses a customer's "existing household smart meter" to track both home and PEV usage. Rates vary from \$0.23 / kWh off-peak to \$0.54 / kWh on-peak.
- **EV-TOU-5:** non-tiered, TOU rate that uses a customer's "existing household smart meter" to track both home and PEV usage. Rates vary from \$0.09 / kWh super-off-peak to \$0.53 / kWh on-peak; this plan also charges a \$16 per month service fee.<sup>122</sup>

**C.4 Multiple Submeter MDMA's and PEVs operating behind a primary meter**

The decision defines the topic of "Multiple Submeter MDMA's and PEVs operating behind a primary meter" as: "Total number of Submeter MDMAs (and distinct business models), and PEVs operating behind the primary utility meter for SFH [single family home], MDU [multiple dwelling unit] and CF [commercial facility] customers. Compare total number for submetering to a) separate PEV metering, and b) Submeter Scenario 1."

In Phase 2 of the pilot the initial intent was to allow customers to participate as single or multiple customer of record (SCOR or MCOR) which would give them a choice of receiving their PEV charging bill from the utility or MDMA. MDMAs stated there was not enough time in the Phase 2 enrollment period to market and sell to commercial customers, which is why they did not apply for any MCOR use cases. This resulted in Phase 2 of the pilot proceeding with only a SCOR option, similarly to Phase 1 of the pilot.

<sup>120</sup> More information is available online:

[https://www.pge.com/en\\_US/residential/rate-plans/rate-plan-options/electric-vehicle-base-plan/electric-vehicle-base-plan.page](https://www.pge.com/en_US/residential/rate-plans/rate-plan-options/electric-vehicle-base-plan/electric-vehicle-base-plan.page)

<sup>121</sup> SCE currently has approximately 600 customers outside of this pilot with separate PEV submetering. The estimated number of PEV customers without submetering is 127,350. More information is available online:

<https://www.sce.com/wps/portal/home/residential/rates/residential-rates/>

<sup>122</sup> More information is available on the SDG&E rate webpage:

<https://www.sdge.com/residential/pricing-plans/about-our-pricing-plans/electric-vehicle-plans>

### C.5 Utility disconnection capability

The decision defines the topic of “utility disconnection capability” as: “Determine whether the utility has physical ability to disconnect electric service to customer receiving submetering service.”

Disconnection has a straightforward solution for SCOR cases: one customer is responsible for the primary meter less charging and for a submeter with car charging; if all or part of the bill is unpaid, the utility can disconnect the primary meter.

The solution for MCOR cases is less clear because there are multiple parties in the agreement. The utility can disconnect the virtual submeter in the IT system, but cannot disconnect electricity to the submeter. In the event that a disconnect of submetering services was warranted, the MCOR CEA states, “You (customer) will retain sole responsibility for paying the entire monthly bill including PEV and other charges regardless of any agreement between you and your Submeter MDMA.”

### C.6 Customer satisfaction

The decision defines the topic of “customer satisfaction” as:

- “Process flows identifying all submeter transactions between PEV, Submeter MDMA, and utility from enrollment to billing.
- Level of customer understanding of process, knowledge of rate and of charging requirements, and satisfaction with services rendered.
- Survey of customer motivations to use submetering.
- Options to streamline processes to improve services.
- Total number of customers solicited to participate, applicants, enrollees, retained, and wishing to continue.”

Aspects of this topic are distributed throughout the report. The definition will be broken down into components and the section number of each item will be provided for reference.

- **Process flows identifying all submeter transactions between PEV, Submeter MDMA, and utility from enrollment to billing.**
  - Section 1.3.1 contains a diagram of the data flows and communications after enrollment. Enrollment process flow diagrams are not available.
- **Level of customer understanding of process, knowledge of rate and of charging requirements, and satisfaction with services rendered. Survey of customer motivations to use submetering.**
  - Section 4.4 contains a broad range of topics across all three surveys implemented in Phase 2 of the pilot.
- **Options to streamline processes to improve services.**
  - As noted in Phase 1 of the pilot, many of the opportunities to streamline processes to improve services require large IT system investments which only make financial sense at full scale. A summary of data and billing issues and resolutions are included in Section 4.5.

- **Total number of customers solicited to participate, applicants, enrollees, retained, and wishing to continue.**
  - The enrollment funnel information is not available for all MDMA's. However, one was able to provide details:
    - ~15,000-20,000 click throughs on their ads that led customers to a landing page about the pilot.
    - ~1,000 people filled out a lead form (indicating interest in the pilot).
    - ~13.6% conversion rate to completed enrollment forms.

### C.7 Reliability of Data, Technology, and Service

The decision defines the topic of “reliability of data, technology, and service” as: “Number, frequency, and type of customer issues related to metering accuracy and data accessibility. Ability of submeter MDMA's or utilities to resolve issues. Customer satisfaction with service.”

- Documentation of data and billing issues and resolutions is contained in Section 4.5, and Customer satisfaction is covered in Section 4.4.

### C.8 Service and Technology Innovations

The final decision defines the topic of “Service and data, Technology Innovations” as: “Opportunities to expand submetering tariffs or programs to additional PEV customers (or other customer types who would benefit from submetering, i.e. tenants or customers using preferred resources). Lessons learned that can be applied to Phase 2 on MCOR or future deployments.”

MDMA's provided the following insights via the interview process:

- Process to sell to commercial customers and multi-family dwellings is more time intensive as it requires property manager or HOA approval.
  - Not enough time in the Phase 2 enrollment period to market and sell to commercial customers, which is why MDMA's did not apply for any MCOR use cases.
  - Some site hosts were initially interested in the pilot, but the contract set up and logistics were too time intensive to be cost-effective in the timeframe of the pilot.
- Another driver of PEV adoption would be separate PEV rates with larger price differentials. Customers want simplicity and certainty, which can be provided through separate metering for vehicles and easily understood tariffs that reward the customer for providing charging flexibility.

## C.9 Technology Standardization

The final decision defines the topic of “technology standardization” as: “Identification of opportunities to and implementation of national standards for customer, charging station, and utility communication and analysis of meter and billing data.”

The utilities and MDMAs have some similarities in their perspective on technology standardization, and a conflicting, but interrelated view point.

### Key Utility Takeaways:

- Do not want to create CA-only standards, and want to leverage national standards whenever possible.
- Before diving into developing submetering protocol, need to address the value proposition of submetering.
  - The pilot has shown extremely low demand for residential submetering.

### Key MDMA Takeaways:

- Need standardization around data reporting structure and transfer protocols.
  - FTP sites and manually uploading Excel spreadsheets to portals are a major pain point for data transfers from third parties to utilities. Move towards using APIs.
  - Industry needs to address questions of how to get 15-minute level data (on or off station) and data transfer mechanisms (e.g., Wi-Fi, ZigBee).
- Enrollment process needs to be simplified and streamlined to create as few customer touches as possible.
- Added value in expanding any submetering protocol to the utilities, and the MDMAs recognize the benefit of standards. However, the utilities are concerned about the value of submetering, noting the low demand. Coming from the other perspective, the MDMAs note the enrollment process needs to be simplified, which likely contributed to at least some of the low demand.
- When considering submetering more broadly, and including additional end uses such as solar generation or battery storage, it may be that the demand for submetering across all of these end uses will ultimately be higher than what has been observed in these initial pilots, limited in scope to PEV charging.

## C.10 Cost minimization

The final decision defines the topic of “cost minimization” as: “Costs incurred by pilot administrators in labor, incentives, equipment, manual billing, and service operations. Estimation of budget requirements for Phase 2 testing MCOR. Estimation of potential changes in costs per customer, at scale, achieved through billing automation.” Please see Section 4.6 for the cost analysis of installing a submeter at full scale with automation.

## Appendix D Explanation of SCOR and MCOR Scenarios

Part of the initial goal of the Phase 2 study was to analyze both single and multiple customer of record (SCOR or MCOR) scenarios. Although the study did not include any MCOR customers, we include background information on the SCOR and MCOR scenarios for reference in this appendix. The two SCOR scenarios (SCOR #1 and #2 in Table D-1) are described in the utility advice letters as:

1. Residential (utility customer) pays submeter and primary meter bills.
2. Facility owner/HOA (utility customer) pays submeter and primary meter bills.

The three MCOR scenarios (MCOR #1, #2, and #3 in Table D-1) are described in the utility advice letters as:

1. MDMA (utility customer) pays submeter bill, and resident (utility customer) pays primary bill less PEV charging usage.
2. Resident (utility customer) pays submeter bill, facility (utility customer) pays primary bills less PEV charging usage.
3. MDMA (utility customer) pays submeter bill, facility (utility customer) pays primary bills less PEV charging usage, Resident (utility customer) pays utility bill for resident's unit and pays MDMA for PEV usage.

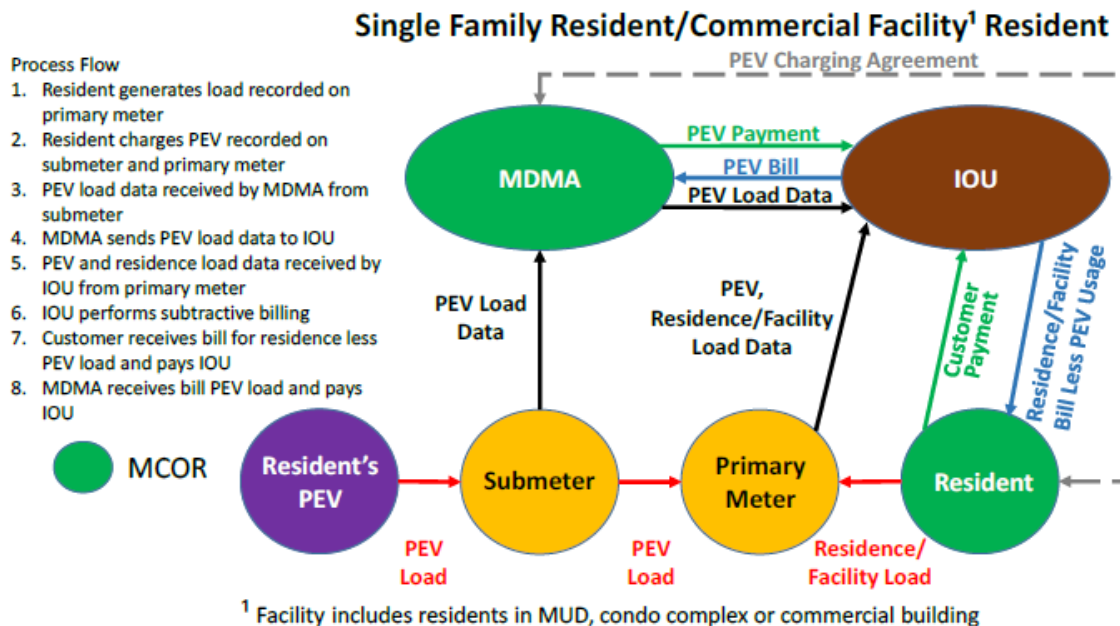
**Table D-1: Billing Scenarios Supported in Phase 2**

Pilot Attributes	Parties and Actions	SCOR		MCOR		
		1	2	1	2	3
Customers of Record	Resident	✓		✓	✓	
	Facility/Owner/HOA		✓		✓	✓
	MDMA			✓		✓
PEV usage netted from	Resident meter	✓		✓		
	Facility/Owner/HOA meter		✓		✓	✓
Utility	Bills resident for PEV usage	✓			✓	
	Bills facility for PEV usage		✓			
	Bills MDMA for PEV usage			✓		✓
MDMA	Bills resident for PEV usage			✓		✓
Parties to Submeter Agreement	Resident & MDMA	✓		✓		✓
	Facility/Owner/HOA & MDMA		✓		✓	✓
	Resident & Facility/Owner/HOA				✓	

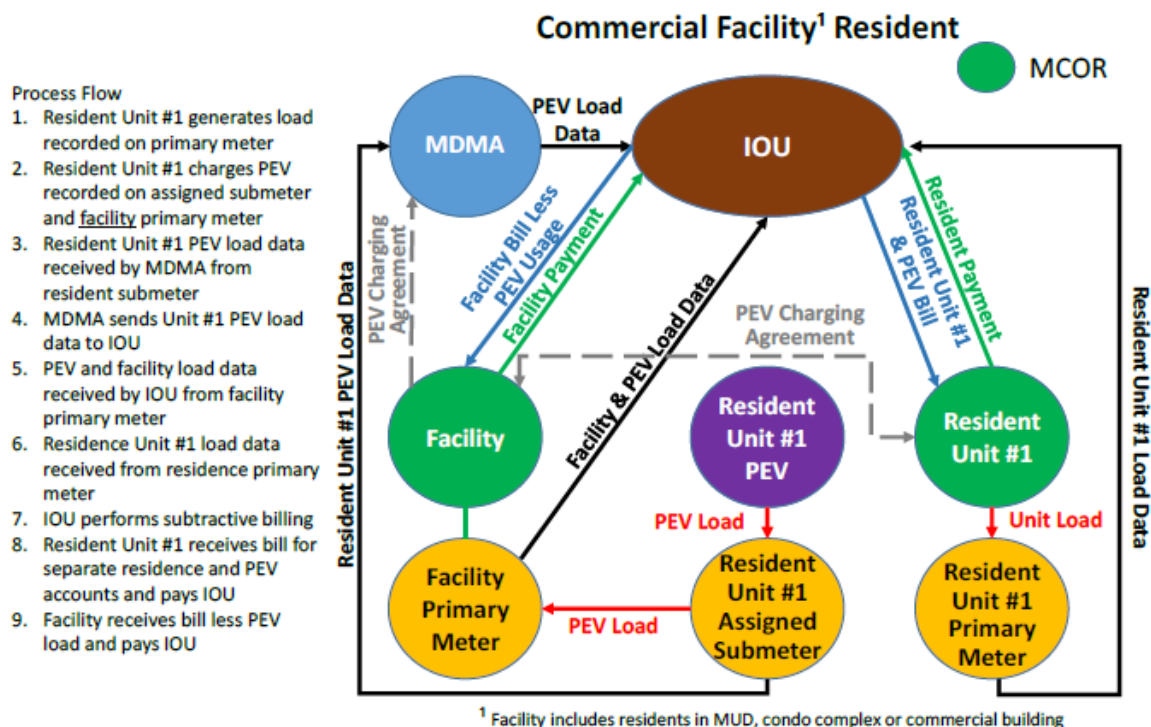
Figure D-1 and Figure D-2 on the following page depict two of three MCOR relationship scenarios that were supported in Phase 2. In the first, the PEV usage, paid for by the MDMA, is subtracted from the facility primary meter and the resident pays for the net primary meter usage. Presumably the MDMA may also separately bill the resident but this will be an agreement completely independent of the utility which is paid by the MDMA for the submeter usage. In the second scenario submetering is used to subtract PEV usage from a facility meter, the resident

pays the utility for the PEV usage, and the facility pays the utility for the primary meter usage less the PEV usage.

**Figure D-1: Phase 2 MCOR Scenario 1—MDMA Pays Submeter Bill and Resident Pays Primary Meter Bill Less PEV Charging**

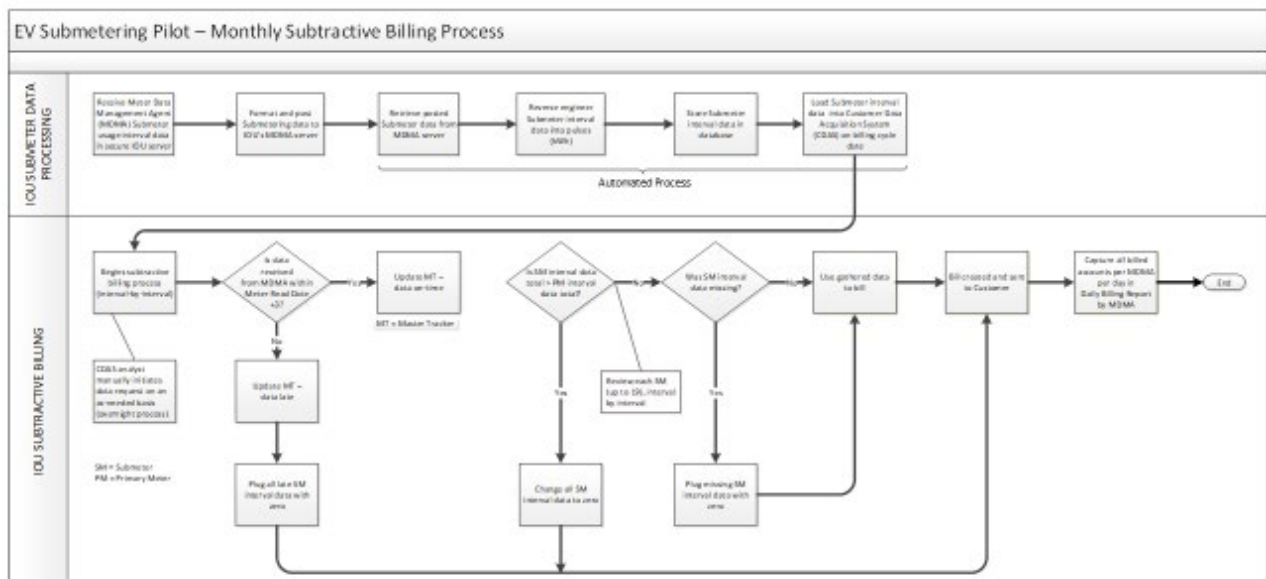
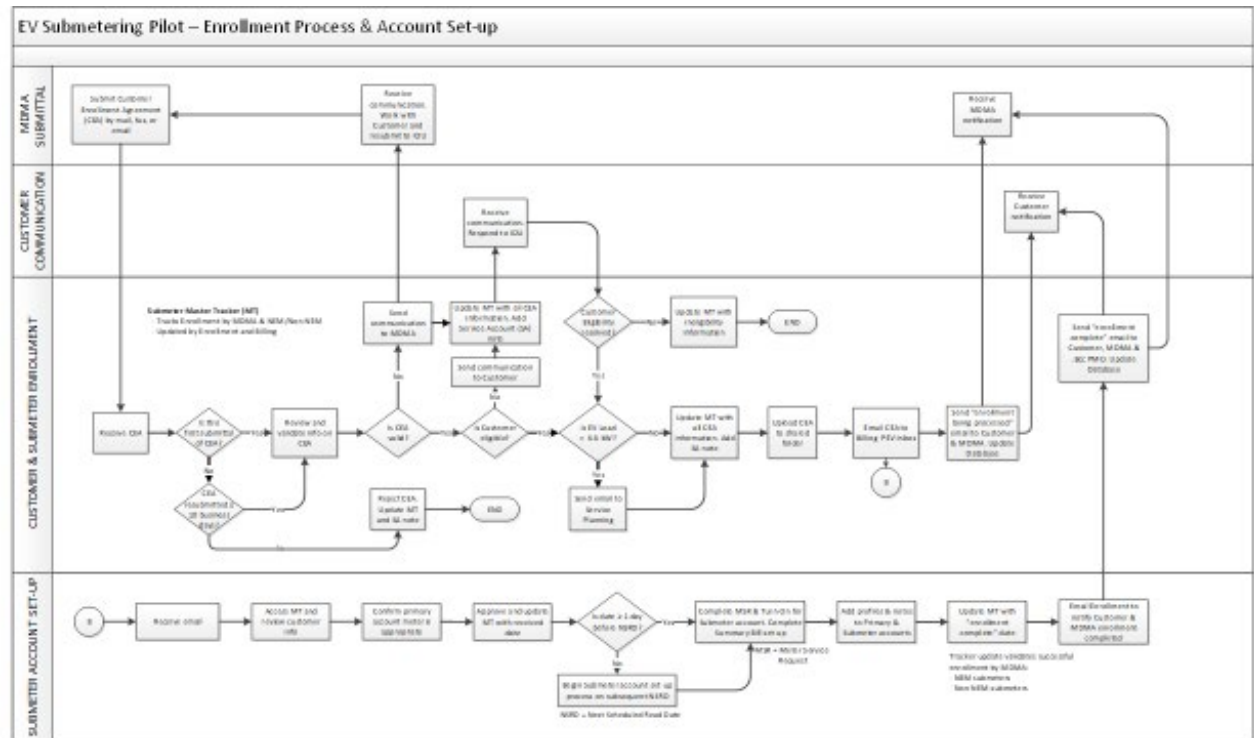


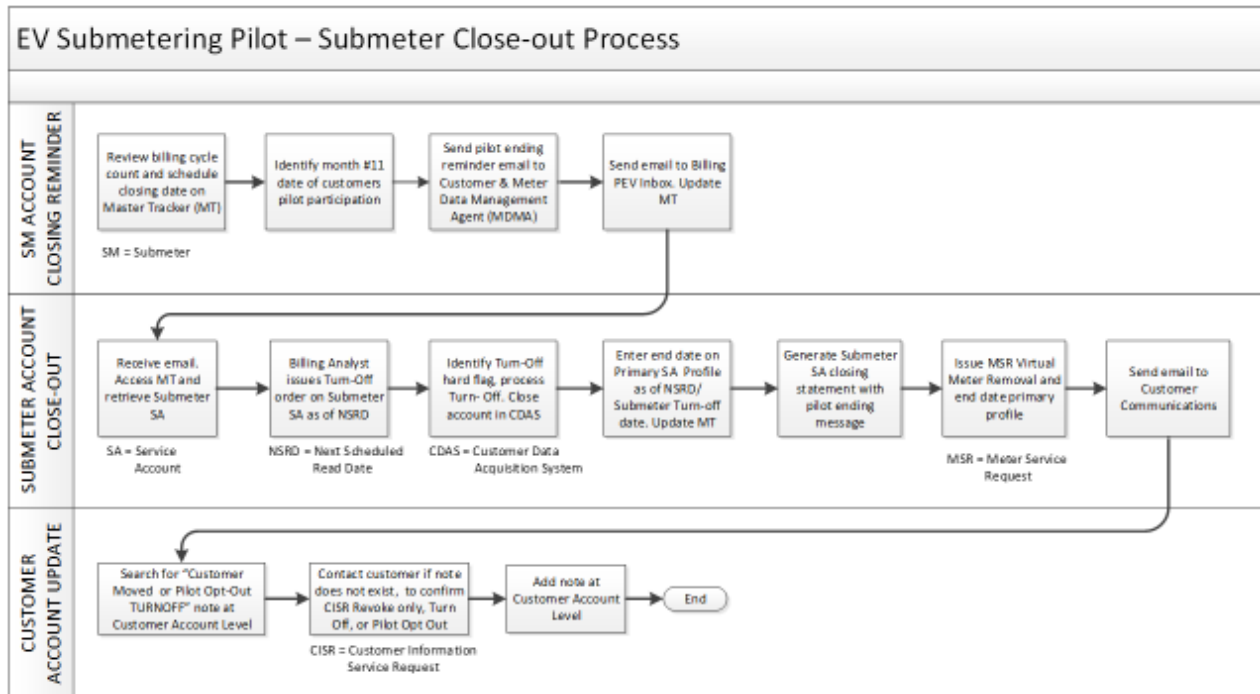
**Figure D-2: Phase 2 MCOR Scenario 2—Resident Pays Submeter Bill and Facility Pays Primary Meter Bill Less PEV Charging**



## Appendix E Process Flow Diagrams

Appendix E contains detailed process flow documents showing the steps that each utility must take to enroll a new customer and set-up their account (top), calculate the monthly bill using the subtractive billing process (middle), and close out the account upon termination (bottom).





## Appendix F Cost Data Collection Template

Appendix F contains the cost data collection template that was provided to the utilities. Information provided by the utilities based on these templates was used to develop the cost estimates in Section 4.6.

### 1. Residential Single Charger

#### A. Traditional separate utility revenue-grade meter

Item	Cost (\$)	Entity Paying Costs (Cust, Utility/GRC, MDMA)	Cost Assumptions (Cost per what)	Comments
Pedestal Unit Cost (meter mounting location)	\$0.00	Customer	Cost per meter	Utilities to provide
Pedestal Labor (mounting location location)	\$0.00	Customer	Cost per meter	Utilities to provide
Utility Meter	\$0.00	Utility / GRC	Cost per meter	Utilities to provide
Utility Meter Labor	\$0.00	Utility / GRC	Cost per meter	Utilities to provide
Other Costs (Please describe and/or add rows)				
<b>Total Cost to Customer</b>	<b>\$0.00</b>	<b>Customer</b>	<b>Cost per meter</b>	
<b>Total Cost to Utility / GRC</b>	<b>\$0.00</b>	<b>Utility / GRC</b>	<b>Cost per meter</b>	
<b>Total Cost to Customer + Utility / GRC</b>	<b>\$0.00</b>	<b>Customer + Utility / GRC</b>	<b>Cost per meter</b>	

#### B. 3rd Party submetering at full scale with automation

Item	Cost (\$) / Assumptions	Entity Paying Costs (Cust, Utility/GRC, MDMA)	Cost Assumptions (Cost per what)	Comments
<b>Assumptions</b>				
Year used for EV Forecast	2022	N/A	N/A	Please update, just a placeholder
Forecast of EV Ownership	405,000	N/A	N/A	Please update, just a placeholder
% of EV Owners interested in submetering	5%	N/A	N/A	Please update, just a placeholder
Number of EV customers used for cost estimate	20,250	N/A	N/A	Please update, just a placeholder
<b>One Time Costs</b>				
Cost to Establish Protocols	\$0.00	Utility / GRC	One Time Cost (Total)	Utilities to provide
Updating Systems for Full Billing / Data Automation	\$0.00	Utility / GRC	One Time Cost (Total)	Utilities to provide
Submeter / EVSE Cost	\$0.00	Customer	One Time Cost (Per Submeter)	To be requested from MDMA
Installation Cost	\$0.00	Customer	One Time Cost (Per Submeter)	To be requested from MDMA
Incentives	\$0.00	MDMA	One Time Cost (Per Submeter)	To be requested from MDMA
Other Costs (Please describe and/or add rows)				
<b>Total Cost to Customer</b>	<b>\$0.00</b>	<b>Customer</b>	<b>Cost per submeter</b>	
<b>Total Cost to MDMA</b>	<b>\$0.00</b>	<b>MDMA</b>	<b>Cost per submeter</b>	
<b>Total Cost to Utility / GRC</b>	<b>\$0.00</b>	<b>Utility / GRC</b>	<b>Cost per submeter</b>	
<b>Annual Recurring Costs</b>				
Operations & Administration Labor Costs	\$0.00	Utility / GRC	Cost per submeter	Utilities to provide
Other Costs (Please describe and/or add rows)	\$0.00		Cost per submeter	
<b>Total Cost to Customer</b>		<b>Customer</b>	<b>Cost per submeter</b>	
<b>Total Cost to MDMA</b>		<b>MDMA</b>	<b>Cost per submeter</b>	
<b>Total Cost to Utility / GRC</b>		<b>Utility / GRC</b>	<b>Cost per submeter</b>	

#### C. Submetering Pilot Costs

Item	Cost (\$) □	Entity Paying Costs (Cust, Utility/GRC, MDMA)	Cost Assumptions (Cost per what)	Comments
Total Annual Administrative, Manual Billing, and Service Operations Cost		Utility / GRC	Cost per submeter	Utilities to provide
Submeter / EVSE Cost		Customer	One Time Cost (Per Submeter)	To be requested from MDMA
Installation Cost		Customer	One Time Cost (Per Submeter)	To be requested from MDMA
Incentives		MDMA	One Time Cost (Per Submeter)	To be requested from MDMA
Other Costs (Please describe and/or add rows)				

## Appendix G Third-Party Lab Testing Report

Appendix G contains a redacted version of the independent lab testing report developed by MET Labs, based in Baltimore Maryland. Results were provided in a report titled “TEL99908-PGE ALL TESTS USC Rev 1” delivered to Nexant on November 1, 2018. The attached report is redacted because details of the specific test results are confidential. Non-redacted versions were provided to the utilities and CPUC for review. The MDMAs each received a copy of the report where their specific tests were not redacted so they could review their own results.

In Microsoft Word versions of this report, the report is embedded as a PDF document. In the final PDF version of this report the MET Labs report will be appended following this page.

Redacted Version of MET Labs report “TEL99908-PGE ALL TESTS USC Rev 3”<sup>1</sup>



TEL99908-PGE ALL  
Tests USC Rev 3\_Re

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<sup>1</sup> See Page iii of the attached report for description of revisions. Error corrections in revision 3 were on pages 18, 20, and 22 related to the test descriptions. Test descriptions and outcomes in the related test results tables on pages 19, 21, and 23 were correct and did not change.



HEADQUARTERS: 914 WEST PATAPSCO AVENUE • BALTIMORE, MARYLAND 21230 • PHONE (410) 354-3300 • FAX (410) 354-3313

Nexant  
101 2nd St,  
San Francisco, CA 94105

April 12, 2019

Dear Eric T. Bell,

Enclosed is the TEL test report for compliance testing of the Nexant, Submeter, tested to the requirements of customer test plan.

Thank you for using the services of MET Laboratories, Inc. If you have any questions regarding these results or if MET can be of further service to you, please feel free to contact me.

Sincerely yours,  
MET LABORATORIES, INC.

A handwritten signature in black ink, appearing to read "Jesse Trawinski". The signature is fluid and cursive, with a large initial "J" and "T".

Jesse Trawinski  
Documentation Department

Reference: (\Nexant\TEL99908-PGE ALL TESTS USC Rev 2)

Certificates and reports shall not be reproduced except in full, without the written permission of MET Laboratories, Inc. This letter of transmittal is not a part of the attached report.



HEADQUARTERS: 914 WEST PATAPSCO AVENUE • BALTIMORE, MARYLAND 21230 • PHONE (410) 354-3300 • FAX (410) 354-3313

## **Test Report**

For the

**Nexant  
Submeter**

Tested under

**Customer Test Plan**

**MET Report: TEL99908-PGE ALL TESTS USC Rev 2**

**November 21, 2018**

Prepared For:

**Nexant  
101 2nd St,  
San Francisco, CA 94105**

**Prepared By:  
MET Laboratories, Inc.  
914 West Patapsco Ave.  
Baltimore MD 21230**

## Test Data

For the

**Nexant  
Submeter**

Tested under

**Customer Test Plan**

**MET Report: TEL99908-PGE ALL TESTS USC Rev 2**



Michael DeVilbiss  
Project Engineer



Jesse Trawinski  
Documentation Department



Jim Reed,  
Manager, Meter Accuracy Lab

---

## Report Status Sheet

Revision	Report Date	Reason for Revision
Ø	October 24, 2018	Initial Issue.
1	November 1, 2018	Added notes in section E
2	November 21, 2018	Addition of Corrected Schematic of testing and additional details in test setup
3	April 12, 2019	Correction of errors

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## 1.0 Executive Summary

MET Laboratories, Inc. was contracted by Nexant to perform acceptance testing to Customer Test Plan criteria on the Submeters under the Nexant purchase order number #18-1006.

The tests were based on Customer Test Plan and Customer Order #18-1006.

The results obtained relate only to the item(s) tested.

Test Name and Meter Tested	Test Status
Test #5 - No Load / Creep Test	
ChargePoint - CPH25 - 160941001398	Compliant
AeroVironment - EVSE-RS - SOS01071700569	Compliant
JuiceBox - Pro 40 - 0817010902030459985217248903	Compliant
Test #6 - Full Load Test	
ChargePoint - CPH25 - 160941001398	Not Compliant
AeroVironment - EVSE-RS - SOS01071700569	Not Compliant
JuiceBox - Pro 40 - 0817010902030459985217248903	Not Compliant
3.5 Hour Tests	
ChargePoint - CPH25 - 160941001398	Not Compliant
AeroVironment - EVSE-RS - SOS01071700569	Not Compliant
JuiceBox - Pro 40 - 0817010902030459985217248903	Not Compliant

## 2.0 Equipment Configuration

### A. Overview

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform an Acceptance Test of the Nexant, Submeters. The tests were based on Customer Test Plan. The tests described in this document were formal tests as described in the customer test plan. The objective of the testing was to verify compliance of the Equipment Under Test (EUT) to the requirements of the aforementioned specifications.

<b>Model(s) Tested:</b>	Submeters
<b>Model(s) Covered:</b>	Submeters
<b>Description of EUT</b>	6 plug-in electric vehicle (PEV) chargers/submeters were provided for testing. 3 separate models, 2 samples of each. They are designed to charge PEVs and transmit the electricity consumption data kWh to the vendor, who then provides it to the electric utility for billing. These
<b>Analysis:</b>	The results obtained relate only to the item(s) tested.
<b>Environmental Test Conditions:</b>	Temperature: 15-35° C
	Relative Humidity: 30-60%
	Barometric Pressure: 860-1060 mbar
<b>Evaluated by:</b>	Michael DeVilbiss
<b>Date:</b>	November 21, 2018

### B. References

<b>ISO 1012-1: 1992 (E)</b>	Quality Assurance Requirements for Measuring Equipment
<b>Customer Test Plan</b>	Pacific Gas & Electric, PEVSP Phase 2 Pilot, EVSE Charger Accuracy Test Plan - Based on ANSI C12.1 - 2014 - Customer Specific Test Program

### C. Test Site

All testing was performed in a limited access test laboratory. This facility is located at MET Laboratories, Inc., 914 West Patapsco Avenue, Baltimore, Maryland 21230.

This testing was conducted in the Environmental Simulation Lab at MET Laboratories, Inc. All equipment used in making physical determinations is accurate and bears recent traceability to the National Standards and Technology.

### D. Modifications

#### a) Modifications to the EUT

No modifications to the EUT were required.

#### b) Modifications to the Test Standard

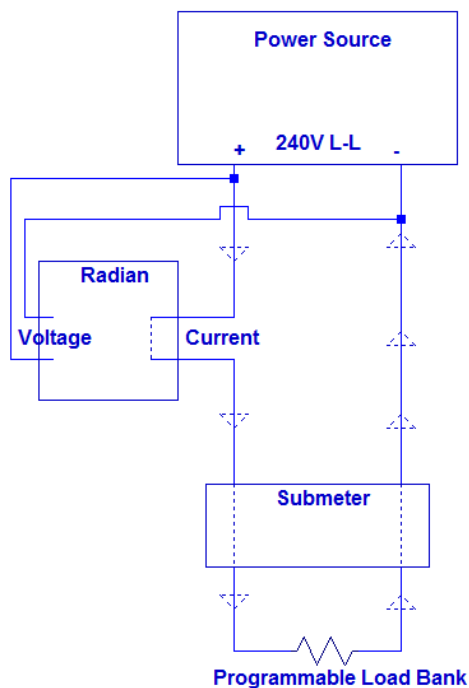
necessary.

No modifications to the Test Standard were

### E. Mode of Operation

The chargers/submeters will have varying levels of load connected for varying durations as specified in the testing specification document provided by PG&E. This is provided as a separate document.

Meter Form	Model/Part Number	Serial Number
PEV Charger / Submeter	ChargePoint CPH25	160941001398
PEV Charger / Submeter	ChargePoint CPH25	161341001877
PEV Charger / Submeter	Aerovironment EVSE-RS	SOS01071700569
PEV Charger / Submeter	Aerovironment EVSE-RS	SOS01071700487
PEV Charger / Submeter	JuiceBox Pro 40	0817010902030470918217248903
PEV Charger / Submeter	JuiceBox Pro 40	0817010902030459985217248903



In the schematic above the loop current flows through the circuit. The 240V L-L is applied on the current loop as well. The Radian was measuring power upstream from the submeter, i.e. it was measuring power delivered directly from the power source. The Radian is reading the same power as the submeter in the setup.

The losses through the Radian are less than 1mOhm and the cables are negligible (approximately 4mOhm). The Radian and the submeter share the same voltage and current in the setup.

Breakdown of the cables used in the test setup:

- Cables from Power Source to Radian to measure voltage: 14AWG, ~6.5ft
- Cable from + terminal of Power Source to Radian: 6 AWG, ~6.5ft
- Cable from Radian to Submeter: 6 AWG, ~6.5ft
- Cable from – terminal of Power Source to Submeter: 10 AWG, ~4ft
- Downstream from the submeter was the 25ft plug that was supplied with the submeter and the adapter box with ~7ft cable

## **F. Monitoring Method Used During Testing**

Under lab testing condition the NIST HB44 T.2 load test tolerances state:

T.2. Load Test Tolerances.

T.2.1. EVSE Load Test Tolerances. – The tolerances for EVSE load tests are:

- (a) Acceptance Tolerance: 1.0 %; and
- (b) Maintenance Tolerance: 2.0 %.

Consumption data is available via the smartphone app associated with each charger module. Successful performance of the intended function is that the charger provides load, data is transmitted to the cloud based platform via wifi, and the smartphone app receives the charging load details. The charging load details from the smart phone app must be within 1% of the actual kWh as measured by MET Labs in order to pass the standard. The tests/modes of operation are provided in the separate PG&E test plan.

## **G. Disposition of EUT**

The test sample including all support equipment (if any), submitted to the Environmental Simulation Lab for testing was returned to Nexant upon completion of testing.

### 3.0 Test #5 - No Load / Creep Test, Test Data

**Test Requirement:** With no load applied confirm any creep on the 2S meters

**Test Procedure:**

- A. EUT Current and Voltage were checked with no Load Applied to the meter.
- B. After 10 minutes of No Load, EUT Current and Voltage were checked.
- C. After 30 minutes of No Load, EUT Current and Voltage were checked.
- D. Testing was performed on all 3 meters.

**Test Results:** Compliant

**Test Date:** 06/29/18 – 10/22/18

**Test Engineer:** Michael DeVilbiss

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan		
<b>Test Name:</b>	5 - No Load/Creep		
<b>EUT:</b>	ChargePoint		
<b>Model:</b>	CPH25		
<b>Serial Number:</b>	160941001398		
<b>Voltage:</b>	240V L-L		
<b>MET Job #:</b>	99908		
<b>Engineer:</b>	Michael DeVilbiss		
<b>Date:</b>	10/1/2018		
<b>Condition</b>	<b>Current</b>	<b>Voltage</b>	<b>Delivered kWh</b>
t = 0 min	0	240	0
t = 10 min	0	240	0
t = 30 min	0	240	0
<b>Results:</b>	Compliant		

**Table 1. Test #5 - No Load / Creep Test, ChargePoint - CPH25 – 160941001398, Test Results**

Notes: The kWh register on the ChargePoint app did not increment when no load was applied to the EV charger over a period of 30 minutes.

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan		
<b>Test Name:</b>	5 - No Load/Creep		
<b>EUT:</b>	AeroVironment		
<b>Model:</b>	EVSE-RS		
<b>Serial Number:</b>	SOS01071700569		
<b>Voltage:</b>	240V L-L		
<b>MET Job #:</b>	99908		
<b>Engineer:</b>	Michael DeVilbiss		
<b>Date:</b>	9/25/2018		
<b>Condition</b>	<b>Current</b>	<b>Voltage</b>	<b>Delivered kWh</b>
t = 0 min	0	240	0
t = 10 min	0	240	0
t = 30 min	0	240	0
<b>Results:</b>	Compliant		

**Table 2. Test #5 - No Load / Creep Test, AeroVironment - EVSE-RS - SOS01071700569, Test Results**

Notes: The kWh register on the EMotorWerks app did not increment when no load was applied to the EV charger over a period of 30 minutes.

Test Plan:	EVSE Charger Accuracy Test Plan		
Test Name:	5 - No Load/Creep		
EUT:	JuiceBox		
Model:	Pro 40		
Serial Number:	0817010902030459985217248903		
Voltage:	240V L-L		
MET Job #:	99908		
Engineer:	Michael DeVilbiss		
Date:	9/28/2018		
Condition	Current	Voltage	Delivered kWh
t = 0 min	0	240	0
t = 10 min	0	240	0
t = 30 min	0	240	0
Results:	Compliant		

**Table 3. Test #5 - No Load / Creep Test, JuiceBox - Pro 40 – 0817010902030459985217248903, Test Results**

Notes: The kWh register on the EMotorWerks app did not increment when no load was applied to the EV charger over a period of 30 minutes.



Photograph 1. Test #5 - No Load / Creep Test, Test Setup

MET #	Equipment	Manufacturer	Model #	Last Cal	Cal Due
4T7347	DYTRONIC REFERENCE STANDARD	RADIAN RESEARCH	RD-20-203	7/18/2018	7/18/2019
4T1632	AC/DC POWER SOURCE SWITCHING AMPLIFIER MASTER UNIT	ELGAR	SW 5250 MHZ	SEE NOTE	
4T1628	SW POWER DISTRIBUTION UNIT	ELGAR (XANTREX)	SW PDU	SEE NOTE	
4T1630	SW SLAVE	ELGAR (XANTREX)	SW 5250S-1-0-0	SEE NOTE	
4T1631	SW SLAVE	ELGAR (XANTREX)	SW 5250S-1-0-0	SEE NOTE	
4T9543	3-CHANNEL ALARM TIMER	CONTROL COMPANY	06-662-5, 11725863	12/11/2017	12/11/2019
4T7338	TRUE RMS INDUSTRIAL MULTIMETER	EXTECH INSTRUMENTS	EX530	9/23/2017	3/23/2019
(RENTAL)	AC LOAD	NH RESEARCH INC.	4600	9/18/2018	9/18/2019
(RENTAL)	AC LOAD	NH RESEARCH INC.	4600	1/4/2018	1/4/2019
(RENTAL)	AC LOAD	NH RESEARCH INC.	4600	1/4/2018	1/4/2019

Table 4. Test #5 - No Load / Creep Test, Test Equipment

Note: Functionally verified test equipment is verified using calibrated instrumentation at time of testing.

## 4.0 Test #6 - Full Load Test, Test Data

### Test Procedure:

**Meter: ChargePoint - CPH25 – 160941001398 Meter:**

- A. 100% current of the charger's rating was applied to EUT at 240 V and at 100% Power Factor.
- B. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- C. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- D. 100% current of the charger's rating was applied to EUT at 240 V and at 81% Power Factor.
- E. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- F. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- G. 100% current of the charger's rating was applied to EUT at 250 V and at 100% Power Factor.
- H. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- I. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- J. 100% current of the charger's rating was applied to EUT at 250 V and at 81% Power Factor.
- K. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- L. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- M. 100% current of the charger's rating was applied to EUT at 230V and at 100% Power Factor.
- N. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- O. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- P. 100% current of the charger's rating was applied to EUT at 230 V and at 81% Power Factor.
- Q. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- R. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes

- S. 100% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- T. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- U. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- V. 100% current of the charger's rating was applied to EUT at 220 V and at 81% Power Factor.
- W. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- X. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- Y. 1% current of the charger's rating was applied to EUT at 240 V and at 100% Power Factor.
- Z. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- AA. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- BB. 1% current of the charger's rating was applied to EUT at 250 V and at 100% Power Factor.
- CC. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- DD. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- EE. 1% current of the charger's rating was applied to EUT at 230 V and at 100% Power Factor.
- FF. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- GG. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- HH. 1% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- II. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- JJ. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes

**Test Results:** Not Compliant

**Test Date:** 10/08/18

**Test Engineer:** Michael DeVilbiss

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan										
<b>Test Name:</b>	6 - Full Load Test										
<b>EUT:</b>	ChargePoint										
<b>Model:</b>	CPH25										
<b>Serial Number:</b>	160941001398										
<b>Voltage:</b>	240V L-L										
<b>MET Job #:</b>	99908										
<b>Engineer:</b>	Michael DeVilbiss										
<b>Date:</b>	10/8/2018										
Section	Voltage	Current	Power Factor	Time (min)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
a) 240V, 100% Load, Unity	240	32	1.0	5							
	240	32	1.0	10							
	240	32	1.0	15							
b) 240V, 100% Load, 81% PF	240	32	0.81	5							
	240	32	0.81	10							
	240	32	0.81	15							
c) 250V, 100% Load, Unity	250	32	1.0	5							
	250	32	1.0	10							
	250	32	1.0	15							
d) 250V, 100% Load, 81% PF	250	32	0.81	5							
	250	32	0.81	10							
	250	32	0.81	15							
e) 230V, 100% Load, Unity	230	32	1.0	5							
	230	32	1.0	10							
	230	32	1.0	15							
f) 230V, 100% Load, 81% PF	230	32	0.81	5							
	230	32	0.81	10							
	230	32	0.81	15							
g) 220V, 100% Load, Unity	220	32	1.0	5							
	220	32	1.0	10							
	220	32	1.0	15							
h) 220V, 100% Load, 81% PF	220	32	0.81	5							
	220	32	0.81	10							
	220	32	0.81	15							
a) 240V, 1% Load, Unity	240	0.32	1.0	5							
	240	0.32	1.0	10							
	240	0.32	1.0	15							
b) 250V, 1% Load, Unity	250	0.32	1.0	5							
	250	0.32	1.0	10							
	250	0.32	1.0	15							
c) 230V, 1% Load, Unity	230	0.32	1.0	5							
	230	0.32	1.0	10							
	230	0.32	1.0	15							
d) 220V, 1% Load, Unity	220	0.32	1.0	5							
	220	0.32	1.0	10							
	220	0.32	1.0	15							

Table 5. Test #6 - Full Load Test, ChargePoint - CPH25 – 160941001398, Test Results

**Test Procedure: Meter: AeroVironment - EVSE-RS - SOS01071700569**

- A. 100% current of the charger's rating was applied to EUT at 240 V and at 100% Power Factor.
- B. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- C. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- D. 100% current of the charger's rating was applied to EUT at 240 V and at 50% Power Factor.
- E. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- F. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- G. 100% current of the charger's rating was applied to EUT at 250 V and at 100% Power Factor.
- H. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- I. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- J. 100% current of the charger's rating was applied to EUT at 250 V and at 50% Power Factor.
- K. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- L. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- M. 100% current of the charger's rating was applied to EUT at 230V and at 100% Power Factor.
- N. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- O. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- P. 100% current of the charger's rating was applied to EUT at 230 V and at 50% Power Factor.
- Q. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- R. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- S. 100% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.

- T. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- U. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- V. 100% current of the charger's rating was applied to EUT at 220 V and at 50% Power Factor.
- W. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- X. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- Y. 1% current of the charger's rating was applied to EUT at 240 V and at 100% Power Factor.
- Z. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- AA. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- BB. 1% current of the charger's rating was applied to EUT at 250 V and at 100% Power Factor.
- CC. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- DD. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- EE. 1% current of the charger's rating was applied to EUT at 230 V and at 100% Power Factor.
- FF. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- GG. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- HH. 1% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- II. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- JJ. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes

**Test Results:** Not Compliant

**Test Date:** 09/27/18

**Test Engineer:** Michael DeVilbiss

Test Plan:	EVSE Charger Accuracy Test Plan										
Test Name:	6 - Full Load Test										
EUT:	AeroVironment										
Model:	EVSE-RS										
Serial Number:	SOS01071700569										
Voltage:	240V L-L										
MET Job #:	99908										
Engineer:	Michael DeVilbiss										
Date:	9/27/2018										
Section	Voltage	Current	Power Factor	Time (min)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
a) 240V, 100% Load, Unity	240	32	1.0	5							
	240	32	1.0	10							
	240	32	1.0	15							
b) 240V, 100% Load, 50% PF	240	32	0.5	5							
	240	32	0.5	10							
	240	32	0.5	15							
c) 250V, 100% Load, Unity	250	32	1.0	5							
	250	32	1.0	10							
	250	32	1.0	15							
d) 250V, 100% Load, 50% PF	250	32	0.5	5							
	250	32	0.5	10							
	250	32	0.5	15							
e) 230V, 100% Load, Unity	230	32	1.0	5							
	230	32	1.0	10							
	230	32	1.0	15							
f) 230V, 100% Load, 50% PF	230	32	0.5	5							
	230	32	0.5	10							
	230	32	0.5	15							
g) 220V, 100% Load, Unity	220	32	1.0	5							
	220	32	1.0	10							
	220	32	1.0	15							
h) 220V, 100% Load, 50% PF	220	32	0.5	5							
	220	32	0.5	10							
	220	32	0.5	15							
a) 240V, 1% Load, Unity	240	0.32	1.0	5							
	240	0.32	1.0	10							
	240	0.32	1.0	15							
b) 250V, 1% Load, Unity	250	0.32	1.0	5							
	250	0.32	1.0	10							
	250	0.32	1.0	15							
c) 230V, 1% Load, Unity	230	0.32	1.0	5							
	230	0.32	1.0	10							
	230	0.32	1.0	15							
d) 220V, 1% Load, Unity	220	0.32	1.0	5							
	220	0.32	1.0	10							
	220	0.32	1.0	15							

Table 6. Test #6 - Full Load Test, AeroVironment - EVSE-RS - SOS01071700569, Test Results

**Test Procedure:**

**Meter: JuiceBox - Pro 40 – 0817010902030459985217248903**

- A. 100% current of the charger's rating was applied to EUT at 240 V and at 100% Power Factor.
- B. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- C. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- D. 100% current of the charger's rating was applied to EUT at 240 V and at 50% Power Factor.
- E. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- F. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- G. 100% current of the charger's rating was applied to EUT at 250 V and at 100% Power Factor.
- H. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- I. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- J. 100% current of the charger's rating was applied to EUT at 250 V and at 50% Power Factor.
- K. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- L. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- M. 100% current of the charger's rating was applied to EUT at 230V and at 100% Power Factor.
- N. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- O. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- P. 100% current of the charger's rating was applied to EUT at 230 V and at 50% Power Factor.
- Q. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- R. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- S. 100% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.

- T. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- U. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- V. 100% current of the charger's rating was applied to EUT at 220 V and at 50% Power Factor.
- W. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- X. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- Y. 1% current of the charger's rating was applied to EUT at 240 V and at 100% Power Factor.
- Z. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- AA. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- BB. 1% current of the charger's rating was applied to EUT at 250 V and at 100% Power Factor.
- CC. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- DD. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- EE. 1% current of the charger's rating was applied to EUT at 230 V and at 100% Power Factor.
- FF. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- GG. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes
- HH. 1% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- II. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- JJ. Test points were run and recorded at 5 minutes, 10 minutes, and 15 minutes

**Test Results:** Not Compliant

**Test Date:** 10/01/18

**Test Engineer:** Michael DeVilbiss

Test Plan:	EVSE Charger Accuracy Test Plan										
Test Name:	6 - Full Load Test										
EUT:	JuiceBox										
Model:	Pro 40										
Serial Number:	0817010902030459985217248903										
Voltage:	240V L-L										
MET Job #:	99908										
Engineer:	Michael DeVilbiss										
Date:	10/1/2018										
Section	Voltage	Current	Power Factor	Time (min)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
a) 240V, 100% Load, Unity	240	32	1.0	5							
	240	32	1.0	10							
	240	32	1.0	15							
b) 240V, 100% Load, 50% PF	240	32	0.5	5							
	240	32	0.5	10							
	240	32	0.5	15							
c) 250V, 100% Load, Unity	250	32	1.0	5							
	250	32	1.0	10							
	250	32	1.0	15							
d) 250V, 100% Load, 50% PF	250	32	0.5	5							
	250	32	0.5	10							
	250	32	0.5	15							
e) 230V, 100% Load, Unity	230	32	1.0	5							
	230	32	1.0	10							
	230	32	1.0	15							
f) 230V, 100% Load, 50% PF	230	32	0.5	5							
	230	32	0.5	10							
	230	32	0.5	15							
g) 220V, 100% Load, Unity	220	32	1.0	5							
	220	32	1.0	10							
	220	32	1.0	15							
h) 220V, 100% Load, 50% PF	220	32	0.5	5							
	220	32	0.5	10							
	220	32	0.5	15							
a) 240V, 1% Load, Unity	240	0.32	1.0	5							
	240	0.32	1.0	10							
	240	0.32	1.0	15							
b) 250V, 1% Load, Unity	250	0.32	1.0	5							
	250	0.32	1.0	10							
	250	0.32	1.0	15							
c) 230V, 1% Load, Unity	230	0.32	1.0	5							
	230	0.32	1.0	10							
	230	0.32	1.0	15							
d) 220V, 1% Load, Unity	220	0.32	1.0	5							
	220	0.32	1.0	10							
	220	0.32	1.0	15							

Table 7. Test #6 - Full Load Test, JuiceBox - Pro 40 – 0817010902030459985217248903, Test Results



Photograph 2. Test #6 - Full Load Test, Test Setup

MET #	Equipment	Manufacturer	Model #	Last Cal	Cal Due
4T7347	DYTRONIC REFERENCE STANDARD	RADIAN RESEARCH	RD-20-203	7/18/2018	7/18/2019
4T1632	AC/DC POWER SOURCE SWITCHING AMPLIFIER MASTER UNIT	ELGAR	SW 5250 MHZ	SEE NOTE	
4T1628	SW POWER DISTRIBUTION UNIT	ELGAR (XANTREX)	SW PDU	SEE NOTE	
4T1630	SW SLAVE	ELGAR (XANTREX)	SW 5250S-1-0-0	SEE NOTE	
4T1631	SW SLAVE	ELGAR (XANTREX)	SW 5250S-1-0-0	SEE NOTE	
4T9543	3-CHANNEL ALARM TIMER	CONTROL COMPANY	06-662-5, 11725863	12/11/2017	12/11/2019
4T7338	TRUE RMS INDUSTRIAL MULTIMETER	EXTECH INSTRUMENTS	EX530	9/23/2017	3/23/2019
(RENTAL)	AC LOAD	NH RESEARCH INC.	4600	9/18/2018	9/18/2019
(RENTAL)	AC LOAD	NH RESEARCH INC.	4600	1/4/2018	1/4/2019
(RENTAL)	AC LOAD	NH RESEARCH INC.	4600	1/4/2018	1/4/2019

Table 8. Test #6 - Full Load Test, Test Equipment

Note: Functionally verified test equipment is verified using calibrated instrumentation at time of testing.

## 5.0 3.5 Hour Test Points Test Data

**Test Procedure:**      **Meter: ChargePoint - CPH25 – 160941001398 Meter:**

- A. 100% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- B. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- C. Test points were run and recorded at 3.5 hours
- D. 100% current of the charger's rating was applied to EUT at 220 V and at 81% Power Factor.
- E. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- F. Test points were run and recorded at 3.5 hours
- G. 1% current of the charger's rating was applied to EUT at 230 V and at 100% Power Factor.
- H. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- I. Test points were run and recorded at 3.5 hours
- J. 1% current of the charger's rating was applied to EUT at 240 V and at 50% Power Factor.
- K. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- L. Test points were run and recorded at 3.5 hours
- M. 100% current of the charger's rating was applied to EUT at 250V and at 100% Power Factor.
- N. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- O. Test points were run and recorded at 3.5 hours
- P. 100% current of the charger's rating was applied to EUT at 250 V and at 81% Power Factor.
- Q. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- R. Test points were run and recorded at 3.5 hours

**Test Results:** Not Compliant

**Test Date:** 10/11/18

**Test Engineer:** Michael DeVilbiss

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan									
<b>Test Name:</b>	3.5 Hr Tests									
<b>EUT:</b>	ChargePoint									
<b>Model:</b>	CPH25									
<b>Serial Number:</b>	160941001398									
<b>Voltage:</b>	240V L-L									
<b>MET Job #:</b>	99908									
<b>Engineer:</b>	Michael DeVilbiss									
<b>Date:</b>	10/11/2018									
Voltage	Current	Power Factor	Time (hr)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
220	32	1.00	3.5							
220	32	0.81	3.5							
230	0.32	1.00	3.5							
240	0.32	0.50	3.5							
250	32	1.00	3.5							
250	32	0.81	3.5							

**Table 9. 3.5 Hour Test, ChargePoint - CPH25 – 160941001398 Meter, Test Results**

**Test Procedure:**                      **Meter: AeroVironment - EVSE-RS - SOS01071700569**

- A. 100% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- B. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- C. Test points were run and recorded at 3.5 hours
- D. 100% current of the charger's rating was applied to EUT at 220 V and at 50% Power Factor.
- E. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- F. Test points were run and recorded at 3.5 hours
- G. 1% current of the charger's rating was applied to EUT at 230 V and at 100% Power Factor.
- H. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- I. Test points were run and recorded at 3.5 hours
- J. 1% current of the charger's rating was applied to EUT at 240 V and at 50% Power Factor.
- K. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- L. Test points were run and recorded at 3.5 hours
- M. 100% current of the charger's rating was applied to EUT at 250V and at 100% Power Factor.
- N. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- O. Test points were run and recorded at 3.5 hours
- P. 100% current of the charger's rating was applied to EUT at 250 V and at 50% Power Factor.
- Q. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- R. Test points were run and recorded at 3.5 hours

**Test Results:** Not Compliant**Test Date:** 10/23/18**Test Engineer:** Michael DeVilbiss

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan									
<b>Test Name:</b>	3.5 Hr Tests									
<b>EUT:</b>	AeroVironment									
<b>Model:</b>	EVSE-RS									
<b>Serial Number:</b>	SOS01071700569									
<b>Voltage:</b>	240V L-L									
<b>MET Job #:</b>	99908									
<b>Engineer:</b>	Michael DeVilbiss									
<b>Date:</b>	10/23/2018									
Voltage	Current	Power Factor	Time (hr)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
220	32	1.00	3.5							
220	32	0.50	3.5							
230	0.32	1.00	3.5							
240	0.32	0.50	3.5							
250	32	1.00	3.5							
250	32	0.50	3.5							

**Table 10. 3.5 Hour Test, AeroVironment - EVSE-RS - SOS01071700569, Test Results**

**Test Procedure:**                      **Meter: JuiceBox - Pro 40 – 0817010902030459985217248903**

- A. 100% current of the charger's rating was applied to EUT at 220 V and at 100% Power Factor.
- B. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- C. Test points were run and recorded at 3.5 hours
- D. 100% current of the charger's rating was applied to EUT at 220 V and at 50% Power Factor.
- E. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- F. Test points were run and recorded at 3.5 hours
- G. 1% current of the charger's rating was applied to EUT at 230 V and at 100% Power Factor.
- H. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- I. Test points were run and recorded at 3.5 hours
- J. 1% current of the charger's rating was applied to EUT at 240 V and at 50% Power Factor.
- K. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- L. Test points were run and recorded at 3.5 hours
- M. 100% current of the charger's rating was applied to EUT at 250V and at 100% Power Factor.
- N. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- O. Test points were run and recorded at 3.5 hours
- P. 100% current of the charger's rating was applied to EUT at 250 V and at 50% Power Factor.
- Q. The meter was confirmed to be running in the forward direction, and the kW on the Radian Standard was confirmed to match the demand on the 2S meter and EV charger.
- R. Test points were run and recorded at 3.5 hours

**Test Results:** Not Compliant**Test Date:** 10/24/18**Test Engineer:** Michael DeVilbiss

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan		
<b>Test Name:</b>	3.5 Hr Tests		
<b>EUT:</b>	JuiceBox		
<b>Model:</b>	Pro 40		
<b>Serial Number:</b>	0817010902030459985217248903		
<b>Voltage:</b>	240V L-L		
<b>MET Job #:</b>	99908		
<b>Engineer:</b>	Michael DeVilbiss		
<b>Date:</b>	10/24/2018		
Voltage	Current	Power Factor	Time (hr)
220	32	1.00	3.5
220	32	0.50	3.5
230	0.32	1.00	3.5
240	0.32	0.50	3.5
250	32	1.00	3.5
250	32	0.50	3.5

Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result

**Table 11. 3.5 Hour Test, JuiceBox - Pro 40 – 0817010902030459985217248903, Test Results**



Photograph 3. 3.5 Hour Test Points, Test Setup

MET #	Equipment	Manufacturer	Model #	Last Cal	Cal Due
4T7347	Dytronic Reference Standard	Radian research	RD-20-203	7/18/2018	7/18/2019
4T1632	AC/DC Power source switching amplifier Master unit	Elgar	SW 5250M	SEE NOTE	
4T1628	SW Power Distribution Unit	Elgar (Xantrex)	SW PDU	SEE NOTE	
4T1630	SW Slave	Elgar (Xantrex)	SW 5250S-1-0-0	SEE NOTE	
4T1631	SW Slave	Elgar (Xantrex)	SW 5250S-1-0-0	SEE NOTE	
4T9543	3-Channel Alarm Timer	Control Company	06-662-5, 11725863	12/11/2017	12/11/2019
4T7338	True RMS Industrial Multimeter	Extech Instruments	EX530	9/23/2017	3/23/2019
(rental)	AC Load	NH Research Inc.	4600	9/18/2018	9/18/2019
(rental)	AC Load	NH Research Inc.	4600	1/4/2018	1/4/2019
(rental)	AC Load	NH Research Inc.	4600	1/4/2018	1/4/2019

**Table 12. 3.5 Hour Test, Test Equipment**

Note: Functionally verified test equipment is verified using calibrated instrumentation at time of testing.

## Appendix H Memo to eMotorWerks Regarding Accuracy Testing

Appendix H contains a memorandum written in response to comments provided by eMotorWerks regarding the accuracy testing.

In Microsoft Word versions of this report, the memorandum is embedded as a PDF document. In the final PDF version of this report the memorandum will be appended following this page.

Memorandum: PEV Submetering - Response to eMotorWerks accuracy related comments\_20181126



PEV Submetering -  
Response to eMotor

**Date:** November 26, 2018

**To:** David Schlosberg, eMotorWerks

**From:** Eric Bell, Nexant, Inc.

**Cc:** Audrey Neuman, CPUC; Will Quinn, PG&E; Al Shepetuk, SCE; Praem Kodiath, SDG&E

**Re:** Response to eMotorWerks accuracy related comments on the PEV Submetering Pilot Phase 2 Report

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## Summary

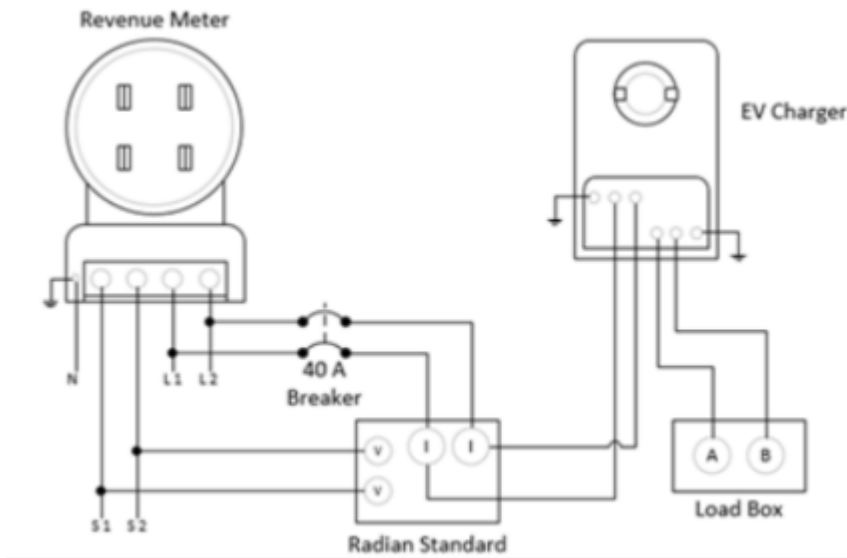
eMotorWerks provided Nexant with comments related to the submeter accuracy portion of the PEV Submetering Pilot Evaluation Phase 2 Report via email on Tuesday, November 13. Nexant convened an internal panel of experts in load measurement and electrical engineering, and worked with MET Labs (the independent testing laboratory) to develop responses to eMotorWerks's comments. This memo repeats the content from the eMotorWerks email along with Nexant's responses so that parties will have an opportunity to see these comments and responses prior to finalization of the report. The report will be updated to include the additional details and implications that are covered in this memo.

## Email Comments from eMotorWerks- November 13, 2018

*Hi Eric,*

*We are reviewing the draft report, but I wanted to preview for you the following concerns we have about the metering. Our metering accuracy expert - Alec Brooks, formerly CTO of AeroVironment - has experience with Quanta testing the EVSE-RS for an SDG&E and the EVSE was qualified with +/- 1% accuracy.*

*The independent laboratory tests had an invalid test setup. They did not measure power and energy at the right place in the system, so all of their results are wrong. Their measurements were upstream of the EVSE, with the measured power going through an unknown length of wiring to the EVSE, through a 40A breaker upstream of the EVSE, then through the EVSE and output cable. But EVSE energy calibration conforming to HB44 is based on energy delivered at the output coupler at the end of the output cable (i.e. energy to the car is what is measured). This is where the AV EVSE energy metering was calibrated to, and i think, also EMW and ChargePoint. The independent laboratory's energy metering location way upstream of the EVSE includes losses in their test setup, the internal EVSE losses, and losses in the output cable. None of these losses were included in AV's reported energy metering values. When SDG&E had the AV meter tested at Quanta in Canada, they verified that the AV meter was within 1%, based on energy delivered at the end of the output cable.*



*This metering point differential could seemingly be the difference between JuiceBox testing within 1% accuracy on every test of 100% PF and non-1% load level. This also brings us to the issue of using 50% Power Factor and 1% Load Levels in testing AND giving equal weighting to these scenarios. As I understand, Electric Vehicles nearly always operate at ~100% Power Factor, and it's actually not even possible for EVSE to pull 1% load unless the EV itself is drawing this amount of amperage (which only occurs in limited low volume scenarios). Of course, when you have such low absolute kWh values, the % variance measurements will be very sensitive.*

*In addition, I presume that the data loggers also could not measure consumption at the output coupler, which would in addition invalidate the percentage +/- 2% compliant readings. A message from Alec Brooks who was part of the submetering protocol development, while at AeroVironment:*

*"When the planning for the submetering pilot was going on I had heard that there would be a number of participant sites where a meter would be installed upstream of the EVSE to validate the EVSE's metering. Back then I pointed out the problem of not measuring at the same point in the system, which would mean that the results would not be directly comparable for calibration checking. It was explained to me that they would not be using these upstream meters for trying to verify the calibration of the EVSE meter, but rather to verify that the reported interval data by the MDMA was consistent with the interval data recorded by the upstream meter."*

*It seems that the constitution of the table on Page 15 directly contradicts this verbal indication and agreement.*

*Obviously it is very late in the process to correct your testing procedure to measure at the proper metering point, consistent with the Submetering Pilot protocols and NIST*

*Handbook 44, but as a result the Report needs to account for this critical error as not to invalidate all of the hard work over 2 pilots to advance this topic.*

*We will continue to review the report and provide edits, but I wanted to make you aware of this material concern of ours.*

## **Response from Nexant**

In the email from eMotorWerks, the comments can be broken down into several topics which will each be discussed in greater detail below:

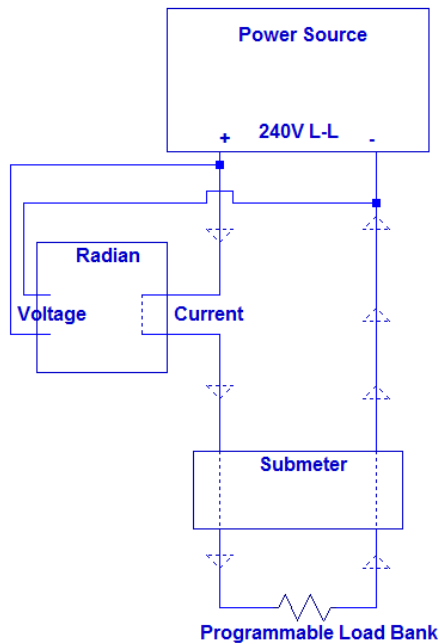
1. Criticisms of the laboratory testing setup- including subjects such as the equipment on the circuit, the metering point, and line loss.
2. Comments about the laboratory testing specifications and results interpretation- specifically, the weighting of the testing scenarios.
3. Comments about the field testing setup with data loggers.

### **Laboratory Testing Setup**

Nexant provided a copy of eMotorWerks' email to MET Labs (the third party testing laboratory) and asked them to respond to criticisms of the laboratory testing setup. In response, MET Labs provided an updated test circuit diagram and clarification regarding the potential for line loss and the implications for using various metering points on the circuit.

Figure 1 below is the updated circuit diagram provided by MET Labs, where they noted the 2S electricity meter and the 40A breaker were both removed to clean up the circuit prior to conducting the tests. They stated these items were removed to add credibility to the test setup through simplification and minimize the potential for losses.

**Figure 1: Updated Laboratory Test Setup Diagram**



In the schematic above, current flows through the circuit at a potential of 240V. The Radian (load recording device) was measuring power upstream from the submeter, i.e. it was measuring power delivered directly from the power source. There would be almost no difference if the Radian was connected to the other branch (right side) of the circuit; any reduction in power recorded by the radian if located in the right side of the circuit would be related to very small  $I^2R$  losses in the additional length of cabling to and from the radian to the programmable load bank and connections to the load bank. The difference in power recorded in the radian was located on the right side of the drawing would be losses in heavy gauge cabling and connections at the load bank which are extremely low. The losses through the Radian ( $< 1\text{mOhm}$ ) and the cables ( $\sim 4\text{mOhm}$ ) in the test setup are negligible (as can be calculated using the test set up cable data provided below). Breakdown of the cables used:

- Cables from Power Source to Radian to measure voltage: 14AWG,  $\sim 6.5\text{ft}$
- Cable from + terminal of Power Source to Radian: 6 AWG,  $\sim 6.5\text{ft}$
- Cable from Radian to Submeter: 6 AWG,  $\sim 6.5\text{ft}$
- Cable from Radian to Submeter: 6 AWG,  $\sim 6.5\text{ft}$
- Cable from – terminal of Power Source to Submeter: 10 AWG,  $\sim 4\text{ft}$
- Downstream from the submeter was the 25ft Jplug that was supplied with the submeter and the adapter box with  $\sim 7\text{ft}$  cable

The test design setup implemented by MET Labs did not include the breaker that eMotorWerks noted as a concern in their comments. The laboratory also noted the point of measurement (location of the Radian) would not result in significant measurement differences if it was

upstream or downstream from the submeter as previously discussed. The wire gauge and lengths were provided above so that engineers can conduct their own line loss calculations. MET Lab concluded that the line losses within the testing setup did not materially affect the outcome of the tests.

eMotorWerks also stated that:

*“EVSE energy calibration conforming to HB44 is based on energy delivered at the output coupler at the end of the output [sic] cable (i.e. energy to the car is what is measured).”*

Unless the EVSE was calibrated to account for line loss in the output cable, the measurements from the testing setup used by MET Labs should be more accurate than if the Radian was connected at the output coupler end of the 25' output cable. We don't know whether the submeters were calibrated to account for line losses in the 25' cable. However, if the EVSEs were calibrated to account for the loss in the output cable, Nexant calculated the expected line loss to provide context to the findings for an example configuration. For example, at 240V, with 32A current flowing through a 25' length of 6 gauge wire, the expected line losses are on the order of 0.137%. eMotorWerks specifically noted “This metering point differential could seemingly be the difference between JuiceBox testing within 1% accuracy on every test of 100% PF and non-1% load level.” To evaluate this statement, the results from the JuiceBox test were examined for sensitivity to potential line loss due to the metering point.

Table 1 shows the test outcomes for the JuiceBox EVSE under a full load of 32A at 240V with a Power Factor of 1 for 5, 10, and 15 minute test durations. While typical charging durations may be longer for actual customer charging, the test scenarios with respect to voltage, current, and power factor reflect normal operating conditions. In the 5 minute test, the EVSE passed, but the results as tested for the 10 and 15 minute intervals were both out of compliance. The test closest to passing was the 10 minute test, with a 1.154% error, which can be reevaluated to take the potential for a different metering point at the end of the output cable and the associated line loss into account. Under the actual test configuration, the Radian was upstream of the submeter. This means that under a case with line loss (as in our example), the Radian would show a greater power consumption measurement than the submeter. We can see from the test results, that the submeter actually shows a higher reading than the Radian, which opens the question of whether there is some sort of line loss correction factor in the submeter. Nexant inquired about the inclusion of such correction, but has not received a response from eMotorWerks.

**Table 1: Select Test Outcomes for JuiceBox EVSE**

Test Plan:	EVSE Charger Accuracy Test Plan										
Test Name:	6 - Full Load Test										
EUT:	JuiceBox										
Model:	Pro 40										
Serial Number:	0817010902030459985217248903										
Voltage:	240V L-L										
MET Job #:	99908										
Engineer:	Michael DeVilbiss										
Date:	10/1/2018										
Section	Voltage	Current	Power Factor	Time (min)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
a) 240V, 100% Load, Unity	240	32	1.0	5	0.000	0.690	0.68401	0.876	100.876	+/- 1.0 %	Pass
	240	32	1.0	10	0.000	1.310	1.29506	1.154	101.154	+/- 1.0 %	Fail
	240	32	1.0	15	0.000	1.960	1.93607	1.236	101.236	+/- 1.0 %	Fail

Given it is unknown if the submeters account for line loss, two scenarios can be imagined if the Radian metering point was moved to the end of the line servicing the output coupler.

1) If the submeters do account for line loss;

If the submeter was calibrated to adjust for line loss from the output cable, the 1.310 kWh recorded at the submeter would factor in the expected 0.137% loss. This means there was actually a higher starting value measured at the submeter, and then a correction was applied to it to remove the line loss and accurately reflect the energy delivered at the output coupler at the end of the output cable. If the Radian were to be positioned at the location of the output coupler, it should show a value decreased by the 0.137% line loss relative to its actual testing location upstream within the circuit. Reducing the Radian by 0.137% to account for the expected line loss if the metering position was changed results in a revised Radian value of 1.293286 kWh ( $1.29506 * (1 - 0.00137)$ ). We are assuming the submeter value is already adjusted for expected line loss and the original value of 1.310 kWh remains the same. The difference between the Radian and the submeter is now slightly larger, at 0.01673 kWh and a difference of 1.292% instead of 1.154% previously. In other words, if the sub-meters are accounting for line losses between the sub-meter and the connector, the error in the measurement of the load is even larger than the error observed in the MET Lab tests. However, the fact that the line loss adjustment increases the difference between the Radian and the sub-meter indicates that it is unlikely that the sub-meters were calibrated to reflect the line loss adjustment.

2) If the submeters do not account for line loss:

If the submeter is not calibrated to account for line loss, then the value measured at the end of the coupling would be expected to be 0.137% lower than observed at the submeter. Given the submeter kWh value is already higher than the Radian, moving the Radian to the end of the output cable only increases the difference in a manner similarly to the case above.

It should be noted that under this testing setup, it is very straight forward to evaluate whether line loss was a potential factor in the accuracy testing. In the case of the JuiceBox EVSE, the majority of the tests under full power showed positive errors relative to the Radian, meaning the submeter was reporting greater energy consumption than the Radian. With the Radian being

upstream of the submeter, this indicates line loss did not negatively affect the accuracy, and moving the metering point increases the difference rather than reducing it.

Table 2 shows the testing outcomes for the AeroVironment EVSE. In one of these tests moving the metering point to the end of output coupler would have made a difference. This is because the measured load levels were lower at the submeter than the Radian, which is opposite from the JuiceBox case. If the Radian was moved to the end of the output coupler for the 10 minute test, we would expect the 0.137% line loss. This would result in a revised Radian value of 1.291528 ( $1.29332 * (1 - 0.00137)$ ). The submeter measurement value was 1.280 ( $1.920 - 0.640$ ). The difference between the two values is -0.01153 ( $1.280 - 1.291528$ ) or -0.893%. Accordingly, moving the test point would have changed the outcome from a difference of -1.022% (out of compliance) to -0.893% (in compliance). However, moving the metering point would not have made a difference for the other two tests in Table 2, or most of the other tests listed in the full report. In summary, it appears the metering point can affect test outcomes, but not enough to change the overall conclusion that the sub-meters generally do not meet the +/- 1% laboratory bench testing standard.

**Table 2: Select Test Outcomes for AeroVironment EVSE**

<b>Test Plan:</b>	EVSE Charger Accuracy Test Plan										
<b>Test Name:</b>	6 - Full Load Test										
<b>EUT:</b>	AeroVironment										
<b>Model:</b>	EVSE-RS										
<b>Serial Number:</b>	SOS01071700569										
<b>Voltage:</b>	240V L-L										
<b>MET Job #:</b>	99908										
<b>Engineer:</b>	Michael DeVilbiss										
<b>Date:</b>	9/27/2018										
Section	Voltage	Current	Power Factor	Time (min)	Initial KWh Read	Final KWh Read	Radian KWh Accumulation	% Error	% Registration	Limit	Result
a) 240V, 100% Load, Unity	240	32	1.0	5	0.020	0.640	0.65152	-4.837	95.163	+/- 1.0 %	Fail
	240	32	1.0	10	0.640	1.920	1.29322	-1.022	98.978	+/- 1.0 %	Fail
	240	32	1.0	15	0.040	1.890	1.88264	-1.734	98.266	+/- 1.0 %	Fail

### **Laboratory Testing Specifications and Results Interpretation**

eMotorWerks also provided comments regarding the weighting of the testing scenarios. The utilities jointly developed the high level test specifications with Nexant. PG&E internal metering specialists further developed the specifics, and the final tests were then reviewed by the utilities and Nexant. It is Nexant's understanding that the test scenarios were based of the ANSI C12 metering standard. Nexant has reached out to the utilities for any additional background information on the development of the testing scenarios, and will include any pertinent background information in the report as additional documentation.

eMotorWerks primary concern was the weighting of the individual tests were biased towards tests of "edge cases" such as low power factor or load levels that aren't as common as full load testing. Nexant does not intend to change how the testing outcomes are reported, but is willing to document eMotorWerks concerns regarding the weighting of the testing in the report. We are also willing to include a non-redacted set of test results in the appendix and refer the reader to the specific testing outcomes such that they can have the full data to draw their own

conclusions. Should eMotorWerks prefer to have the non-redacted test results included in the report appendix, please indicate as such in writing.

### **Field Testing Setup with Data Loggers**

eMotorWerks claims the field testing using data loggers is invalid due to the metering point not being at the output coupler at the end of the output cable. Nexant recognized the metering point (for the data loggers used in the study) as a confounding factor in this analysis, and took account of this factor by analyzing the accuracy of the meters at varying accuracy thresholds (i.e.,  $\pm 2\%$  and  $\pm 5\%$ ) over varying time intervals (i.e., 15 minutes and 24 hours).

One of the primary challenges in using submetering to perform subtractive billing is that the measurement of consumption at the vehicle will never exactly equal the measurement of power consumption associated with vehicle charging at the utility service meter. This is because of the line losses that will occur between the service meter and the vehicle. Because of their size and requirement for physical stability and safety, it was not possible to install data loggers downstream of the sub meters in this project (i.e., near the vehicle connectors). Instead the loggers had to be installed somewhere upstream of the charging stations. Because of the varying wiring configurations in the households under study some of the data loggers were installed at the service panel (serving the vehicle charging circuit), and others were installed in the charging station circuit usually just above the EVSE.

To take account of variation in load measurements resulting from location of the data loggers in the circuits under study, additional test thresholds beyond the  $\pm 2\%$  at the 15 minute interval were conducted. These tests included evaluating the accuracy of the sub-meters over 24 hour periods at the  $\pm 2\%$  and  $\pm 5\%$  threshold levels (to allow for losses). Analyzing the accuracy of the sub-meters at the daily level eliminates differences between logger and sub-meter measurements that might have occurred because of slight variations in the time stamps recorded by the loggers and meters for 15 minute intervals. Small differences can result (at 15 minute intervals) when the clock settings for the loggers and the sub-meters are slightly different. These differences average out over a 24 hour period, so the accuracy measurements for the 24 hour intervals should not be significantly influenced by time stamp issues. Increasing the error tolerances to  $\pm 5\%$  is intended to allow for differences (between logger and submeter measurements) that might have arisen as a result of line losses due to the different logger positioning locations. Line losses over a 100' length of 6 gauge wire at 240 volts and 40 amps would produce line losses of approximately 1.3%. Therefore, the likely maximum line losses between the logger installed at the panel and the sub-meter is less than 1.3%, which is well inside of the  $\pm 5\%$  tolerance.

The decision to laboratory test the submeters was not part of the original test plan for the project. It came about when Nexant discovered that the sub-meters were not meeting the field performance standard (i.e.,  $\pm 2\%$  error) and PG&E brought it to our attention that the sub-meters were not meeting the minimum standard for performance in their in house laboratory tests. The tests from the independent laboratory were carried out to independently verify the results of the laboratory testing that had been carried out by PG&E. As discussed above, the laboratory testing confirms there are still issues with accuracy when the complications from the field testing are removed. Furthermore, while the accuracy of the submeter itself was likely a factor in the accuracy issues observed in the field testing, our results show that lost data

through the backhaul system, potentially from customer Wi-Fi issues is undoubtedly a substantially larger factor (than submeter accuracy) affecting the performance of the submetering system for use in subtractive billing. There were many instances where the data loggers in the study registered charging, but the submeters did not. These situations produce orders of magnitude higher errors than the small errors arising from calibration of the submeters.

Ultimately, our goal for this evaluation report is to communicate the findings from the evaluation work that took place in an objective manner. We would like to present as much information as possible such that reviewers have enough information to reach conclusions on their own. In the end, the back and forth over the testing specifications and interpretation of results in this round of review and correspondence is a very powerful illustration of the importance of developing a standard for verifying sub-meter accuracy.

## Appendix I Supporting Details for Energy Cost Analysis

**Table I-1: Rates and Prices Used to Determine Lowest Cost Charging Options**

Utility	Rate Type	\$/kWh (Summer Season)		Tariff Name	Source
		On-Peak	Off-Peak or Super Off-Peak		
PG&E	Separately Metered PEV TOU	\$0.47	\$0.13	EV-B	<a href="https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_EV%20(Sch).pdf">https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_EV%20(Sch).pdf</a>
	Whole House EV TOU	\$0.48	\$0.12	EV-A	<a href="https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_EV%20(Sch).pdf">https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_EV%20(Sch).pdf</a>
	Residential Default TOU	\$0.38	\$0.32	E-TOU-C3	<a href="https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-TOU-C3.pdf">https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-TOU-C3.pdf</a>
	Residential Tiered (Non-TOU) Rate- Tier 1 (1%-100% of Baseline)	\$0.22	\$0.22	E-1	<a href="https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-1.pdf">https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-1.pdf</a>
	Residential Tiered (Non-TOU) Rate- Tier 2 (101%-400%)	\$0.28	\$0.28	E-1	<a href="https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-1.pdf">https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-1.pdf</a>
	Residential Tiered (Non-TOU) Rate- High Usage (>400%)	\$0.44	\$0.44	E-1	<a href="https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-1.pdf">https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDULES_E-1.pdf</a>
SCE	Separately Metered PEV TOU	\$0.37	\$0.13	Schedule TOU-EV-1	<a href="https://www1.sce.com/NR/sc3/tm2/pdf/ce114-12.pdf">https://www1.sce.com/NR/sc3/tm2/pdf/ce114-12.pdf</a>
	Whole House EV TOU	\$0.47	\$0.12	Schedule TOU-D Option A	<a href="https://www1.sce.com/NR/sc3/tm2/pdf/ce360.pdf">https://www1.sce.com/NR/sc3/tm2/pdf/ce360.pdf</a>
	Residential Default TOU	\$0.41	\$0.22	Schedule TOU-D Option 4-9	<a href="https://www1.sce.com/NR/sc3/tm2/pdf/ce360.pdf">https://www1.sce.com/NR/sc3/tm2/pdf/ce360.pdf</a>
	Residential Tiered (Non-TOU) Rate- Tier 1 (1%-100% of Baseline)	\$0.17	\$0.17	Schedule D: Domestic Service	<a href="https://www1.sce.com/NR/sc3/tm2/pdf/ce12-12.pdf">https://www1.sce.com/NR/sc3/tm2/pdf/ce12-12.pdf</a>
	Residential Tiered (Non-TOU) Rate- Tier 2 (101%-400%)	\$0.25	\$0.25	Schedule D: Domestic Service	<a href="https://www1.sce.com/NR/sc3/tm2/pdf/ce12-12.pdf">https://www1.sce.com/NR/sc3/tm2/pdf/ce12-12.pdf</a>
	Residential Tiered (Non-TOU) Rate- High Usage (>400%)	\$0.35	\$0.35	Schedule D: Domestic Service	<a href="https://www1.sce.com/NR/sc3/tm2/pdf/ce12-12.pdf">https://www1.sce.com/NR/sc3/tm2/pdf/ce12-12.pdf</a>
SDG&E	Separately Metered PEV TOU	\$0.53	\$0.23	EV-TOU	<a href="http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_EV-TOU.pdf">http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_EV-TOU.pdf</a>
	Whole House EV TOU	\$0.53	\$0.23	EV-TOU-2	<a href="http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_EV-TOU-2.pdf">http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_EV-TOU-2.pdf</a>
	Residential Default TOU	\$0.66	\$0.36	Schedule TOU-DR1	<a href="http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_TOU-DR1.pdf">http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_TOU-DR1.pdf</a>
	Residential Tiered (Non-TOU) Rate- Tier 1 (1%-100% of Baseline)	\$0.27	\$0.27	Schedule DR, Domestic Service	<a href="http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_DR.pdf">http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_DR.pdf</a>
	Residential Tiered (Non-TOU) Rate- Tier 2 (101%-400%)	\$0.47	\$0.47	Schedule DR, Domestic Service	<a href="http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_DR.pdf">http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_DR.pdf</a>
	Residential Tiered (Non-TOU) Rate- High Usage (>400%)	\$0.55	\$0.55	Schedule DR, Domestic Service	<a href="http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_DR.pdf">http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDULES_DR.pdf</a>

## Base Assumptions and Hourly Energy Usage Data

**Table I-2: Cost Estimate Calculations for Results Presented in Section 4.6.3.1**

Example:		SCE Baseline 9, Moderate Climate Zone- Inland city in Los Angeles Basin			
Assumptions:					
PEV with 0.26 kWh per mile efficiency, 33 miles per day, charging of 8.62 kWh per day					
Average Customer Hourly kWh from Opt-in TOU Pilot					
		Summer kWh		Winter kWh	
Hour Start	Ending	Weekday	Weekend	Weekday	Weekend
12:00 AM	1	0.75	0.81	0.52	0.55
1:00 AM	2	0.66	0.7	0.47	0.50
2:00 AM	3	0.59	0.63	0.45	0.47
3:00 AM	4	0.55	0.58	0.45	0.45
4:00 AM	5	0.54	0.55	0.47	0.46
5:00 AM	6	0.55	0.54	0.52	0.49
6:00 AM	7	0.59	0.57	0.59	0.54
7:00 AM	8	0.62	0.62	0.61	0.60
8:00 AM	9	0.65	0.7	0.59	0.64
9:00 AM	10	0.73	0.82	0.60	0.67
10:00 AM	11	0.83	0.96	0.60	0.69
11:00 AM	12	0.95	1.11	0.60	0.70
12:00 PM	13	1.11	1.29	0.61	0.71
1:00 PM	14	1.26	1.47	0.61	0.73
2:00 PM	15	1.42	1.64	0.63	0.75
3:00 PM	16	1.54	1.76	0.66	0.77
4:00 PM	17	1.64	1.81	0.71	0.80
5:00 PM	18	1.68	1.77	0.82	0.86
6:00 PM	19	1.62	1.65	0.89	0.91
7:00 PM	20	1.52	1.52	0.91	0.92
8:00 PM	21	1.44	1.42	0.89	0.89
9:00 PM	22	1.31	1.29	0.81	0.82
10:00 PM	23	1.1	1.1	0.70	0.72
11:00 PM	24	0.91	0.93	0.60	0.62
	Daily kWh	24.58	26.25	15.31	16.22

## Calculations Based on Interval Data

Season:	Summer (Jun-Sep)						Winter (Oct-May)					
	Weekday			Weekend			Weekday			Weekend		
Baseline kWh	13.8			13.8			10.6			10.6		
Household (HH) kWh	24.58			26.25			15.31			16.22		
Charging (CG) kWh	8.62	8.62		8.62			8.62			8.62		
Total kWh	33.2			34.87			23.93			24.84		
<b>Calculations:</b>												
<b>Residential Tiered Rate</b>												
Season:	Summer						Winter					
	Weekday			Weekend			Weekday			Weekend		
	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total
Baseline (HH)	13.8	\$0.17	\$2.35	13.8	\$0.17	\$2.35	10.6	\$0.17	\$1.80	10.6	\$0.17	\$1.80
Tier 2 (HH)	10.78	\$0.25	\$2.70	12.45	\$0.25	\$3.11	4.71	\$0.25	\$1.18	5.62	\$0.25	\$1.41
Tier 2 (CG)	8.62	\$0.25	\$2.16	8.62	\$0.25	\$2.16	8.62	\$0.25	\$2.16	8.62	\$0.25	\$2.16
Total	33.20		\$7.20	34.87		\$7.61	23.93		\$5.13	24.84		\$5.36
<b>Residential Default TOU Rate TOU-D 4-9</b>												
Season:	Summer						Winter					
	Weekday			Weekend			Weekday			Weekend		
	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total
On Peak 4-9 (HH)	7.90	\$0.41	\$3.24				4.22	\$0.29	\$1.22	4.38	\$0.29	\$1.27
Mid-Peak (HH)				8.17	\$0.27	\$2.21	6.19	\$0.28	\$1.73	6.22	\$0.28	\$1.74
Off Peak (HH)	16.66	\$0.22	\$3.67	18.07	\$0.22	\$3.98	4.90	\$0.17	\$0.83	5.66	\$0.17	\$0.96
Off Peak (CG)	8.62	\$0.22	\$1.90	8.62	\$0.22	\$1.90	8.62	\$0.17	\$1.47	8.62	\$0.17	\$1.47
Baseline Credit	13.80	-\$0.08	-\$1.10	13.8	-\$0.08	-\$1.10	10.6	-\$0.08	-\$0.85	10.60	-\$0.08	-\$0.85
Total	33.18		\$7.70	34.86		\$6.97	23.93		\$4.41	24.88		\$4.59
<b>Residential House TOU Rate for TOU-D-Opt A</b>												
Season:	Summer						Winter					
	Weekday			Weekend			Weekday			Weekend		
	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total
On Peak 2-8 (HH)	9.42	\$0.47	\$4.43				4.62	\$0.35	\$1.62			
Mid-Peak (HH)	8.28	\$0.28	\$2.32	19.21	\$0.28	\$5.38	5.32	\$0.27	\$1.44	10.86	\$0.27	\$2.93
Off peak (HH)	6.86	\$0.12	\$0.82	7.03	\$0.12	\$0.84	5.37	\$0.13	\$0.70	5.40	\$0.13	\$0.70
Off Peak (CG)	8.62	\$0.12	\$1.03	8.62	\$0.12	\$1.03	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12
Baseline Credit	13.80	-\$0.08	-\$1.10	13.8	-\$0.08	-\$1.10	10.6	-\$0.08	-\$0.85	10.6	-\$0.08	-\$0.85
Total	33.18		\$7.50	34.86		\$6.15	23.93		\$4.02	24.88		\$3.91
<b>Residential EV Metering (Household on TOU-EV-1 + TOU-D-4-9PM)</b>												
Season:	Summer						Winter					
	Weekday			Weekend			Weekday			Weekend		
	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total
On Peak 4-9 (HH)	7.90	\$0.41	\$3.24	0.00	0.00		4.22	0.29	\$1.22	4.38	\$0.29	\$1.27
Mid-Peak (HH)	0	\$0.00		8.17	\$0.27	\$2.21	6.19	\$0.28	\$1.73	6.22	\$0.28	\$1.74
Off Peak (HH)	16.66	\$0.22	\$3.67	18.07	\$0.22	\$3.98	4.90	\$0.17	\$0.83	5.66	\$0.17	\$0.96
Off Peak (CG)	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12
Baseline Credit	13.80	-\$0.08	-\$1.10	13.80	-\$0.08	-\$1.10	10.6	-\$0.08	-\$0.85	10.60	-\$0.08	-\$0.85
Total	33.18		\$6.92	34.86		\$6.20	23.93		\$4.06	24.88		\$4.25
<b>Residential EV Metering (Household on TOU-EV-1 + Residential Tiered Rate)</b>												
Season:	Summer						Winter					
	Weekday			Weekend			Weekday			Weekend		
	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total	kWh	\$ per kWh	\$ Total
HH Tier 1	13.80	\$0.17	\$2.35	13.80	\$0.17	\$2.35	10.60	\$0.17	\$1.80	10.60	\$0.17	\$1.80
HH Tier 2	10.78	\$0.25	\$2.70	12.45	\$0.25	\$3.11	4.71	\$0.25	\$1.18	5.62	\$0.25	\$1.41
Off Peak (CG)	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12	8.62	\$0.13	\$1.12
Total	33.20		\$6.16	34.87		\$6.58	23.93		\$4.10	24.84		\$4.33



Headquarters

101 2nd Street, Suite 1000

San Francisco CA 94105-3651

Tel: (415) 369-1000

Fax: (415) 369-9700

[www.nexant.com](http://www.nexant.com)

*(End of Attachment C)*